In These Times, Season 3: 20 Years of Discovery in Cosmology (Bonus Segment)

Alex Schein:

Welcome to the OMNIA Podcast: In These Times, Fear and Loathing and Science.

In Episode 1: Facts vs. Feelings, Mark Trodden commented that most of what we would call modern cosmology is a very recent vintage, including many discoveries from just the past few decades.

In this bonus segment, Professor Trodden discusses what this recent research has to say about the Big Bang, gravitational waves, and the expanding universe. Here’s Professor Trodden:

Mark Trodden:

I will in no way attempt to be comprehensive. But there are some things that really stick out, I think, you know, in the period just before I became a faculty member. So, a little over 20 years ago, probably, you know, there was a discovery, I think, which was to many of us very unexpected and has shaped the research agenda of certainly my research agenda, but many of my colleagues in the intervening 20 years. So, I mentioned that the universe is expanding. It means it's getting bigger over time. And what that explicitly means is if you look at a faraway galaxy, then, you know, over time that is receding from us and it's receding from us now, not because it's got some, you know, rocket attached to it or something like that. It's receding because the space time is expanding between us. That's our other esoteric concept, but this is what we mean by the expanding universe. And people have known this for a homing in, on the century now. And, uh, and it's in many ways, a prediction of Einstein's theory of general relativity.

What's more amazing is that about 20 years ago, it was discovered that not only are things moving away, each other in the universe, but in fact, they're moving away faster over time. So this is often referred to as the accelerating universe, and it's entirely unexpected for a number of reasons, not least, because if you take Einstein’s theory of general relativity and you apply it to cosmology, you know, it's a complicated theory, and I could talk forever about why things behave they do. But at those fundamental levels still, space in time is filled with galaxies. Those galaxies attract one another due to gravity. And so you would expect, yeah, maybe they're moving apart, but that should be slowing down because of these forces. But in fact, it's speeding up.

So, sometimes this is called the accelerating universe. Sometimes it's referred to as the dark energy problem. It's a massive question. And I think we are not really close to having a satisfactory, theoretical answer to that question right now, in my opinion. I've certainly spent a lot of the last 20 years thinking about that problem and working on it and thinking about ways in which we might play with both the particle physics and the gravity side of what we know about the universe in ways that are mathematically consistent and yet can lead to this kind of effect. And it turns out that something that's mathematically consistent and not ruled out by observations puts huge constraints on what's allowed. Uh, that could be the answer to this question. So that's a big deal and, and it's, it remains a major topic of research in the community today.

The second thing is, I think, much more recent. Uh, so within the last few years, you know, we've known one prediction of Einstein's theory of general relativity is that when you move masses and energy around in the universe, it should radiate gravitational waves ripples in space time, much in the way that we discovered much earlier in physics, that if you move charged objects around, they radiate electromagnetic waves, and that led to the discovery of radio. So we know now that you can do this in a more complicated way in general relativity to create what are called gravitational waves, not only was that was that predicted by, by Einstein, but in fact was indirectly observed by watching the way in which all butting particular types of orbiting bodies, pulsars, how their all changes all the time by observing them for many, many years and noticing that they get closer and they all get changes.

And that means that must be energy dissipating. You can compare the energy dissipated to the way they behave and it matches beautifully. So that's indirect evidence that there are in fact gravitational waves in the universe and they're being given headset. What happened in the last few years is that due to a very large effort, um, first in the United States, but also now, uh, worldwide, um, we've discovered these gravitational waves directly. So apparatus pieces were built, uh, and in the U.S. that major effort was what's called a LIGO experiment, Laser Interferometer Gravitational-wave Observatory. And, you build these very precise, pieces of equipment. These are huge things -- they aren't something you have in a lab. You build, miles long, a piece of operators to do this, and you measure tiny, tiny variations, and distance has as gravitational waves pass the earth.

And this has been discovered in the last few years. And first of all, it's wonderful. The Nobel Prize for this was given just a couple of years ago for this discovery, but, uh, normally is wonderful, but I think it's sort of the next step in how we then observe the universe and will sort of lead into the next thing really that I want to say has been important. But, you know, when we observe the universe, you hear a lot about astronomers who use telescopes like the Hubble space telescope, but you also hear about radio astronomers, x-ray astronomers, and it may sound like these people are doing observing completely different things, but really they're all observing electromagnetic waves. They're just observing them different parts of what's called electromagnetic spectrum. X-rays are very short wavelength, a high energy type of light, you know, infrared waves or the other end of that spectrum, long wavelength, low energy types of light. Optical observatories give you pictures that you can actually see are right in the visible spectrum, but they're all light.

And most of astronomy and most of what we learned about the universe has been through observing light one way or another, and inferring from that, the way in which bodies are behaving, gravitational waves are fundamentally different. So they provide us with an entirely new completely independent window on the universe. And so this is heralded, what is a much over-used phrase these days, but the era of what's called multi messenger astronomy, where, where you can measure properties of astrophysical bodies, or in my case, what I'm interested in the universe itself, both in light, in all its wavelengths and in gravitational waves. And this is a very powerful way of trying to get at some of these questions that I mentioned at the beginning of our chat. So I think that's extremely exciting. And that's where at the very beginning of that.

You know, I think what's happening with gravitational waves is one example of a longer trending cosmology, which I think has been important again, perhaps in the last 20 years, which is the advent of what people like to call precision cosmology for a long time in cosmology, we were discovering wonderful things, but we weren't measuring them very precisely.

You know, the leftover glow from the big bang microwave background radiation was discovered in the late sixties, mid to late sixties. And that's, uh, you know, for a while, that discovering, that was the most amazing thing you could imagine in that field. But over the last 20, 30 years, that has been turned into a precision science, where measuring the detailed features of that background radiation are a tool that can teach us about the early universe, that link universe, all aspects of cosmic evolution. And I think we're going to see that with gravitational waves, as we have with other things that, this story of discovering something amazing about the universe that you couldn't have imagined measuring before quickly becoming a tool that you use to probe things in the universe that you didn't know how to before is going to happen. So that's another story.

I guess the final thing I'll mention among the many things I could mention is a very theoretical one, which is over the history of physics, really, there has been a lot of utility gained from studying what are called dualities, and that's when you have a physical system described in what might be a very natural way for you to describe it. But the equations that arise that way are very hard to solve. Sometimes somewhat seemingly miraculously people find descriptions of that system that look completely different, but you can prove are equivalent and yet are really easy to solve. And so these are two descriptions, completely distinct of the same phenomenon. So presumably they're related in some deep way, but you might not know how they're related, uh, at the time. But depending on what question you're asking, you know, have two completely complimentary ways of calculating the answer. So, you know, I mentioned earlier that understanding, for example, the earliest times in the universe where gravity and quantum mechanics are important, uh, is a very, very challenging, theoretical, endeavor, and it's in principle very, very hard to calculate with our current tools of gravity and particle physics.

But it's become apparent in the last, again 20 years or so and some of this much more recently, that there are some versions of these dualities that they're called that might allow us to have descriptions of the physics in a different way where calculating could be easier. That's an ongoing subject. We have people in this department who spent far more time thinking about it than I, but I am interested in that subject. And I spent quite a bit of time thinking about it in recent years as applied to the very earliest time living universe. And I think some of those dualities of the risk of it, I'm thinking particularly of something called the AdS/CFT correspondence and something called a double copy, I think hold up promise that we might find ways, you know, sort of cracks in this very difficult calculational edifice to exploit and find our way to some of the answers about what's happening in the early universe.

Alex Schein:

This brings us to the end of our bonus segment of Episode 1 of In These Times: Fear and Loathing and Science, with Professor Mark Trodden.

Please join us for Episode 2: Talking the Talk, where we’ll be talking with a linguistics professor on language – and how we use it, experiment with it, and attempt to control it.

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