Dr. Perry Phillips, Herman Lectures, Part 3, 6-Minute Video Overview

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Welcome to the Explainer. Today we're diving into what is literally the ultimate cosmic detective story. The Big Bang, Dark Matter, and the Multiverse.

We're trying to piece together the origin, the structure, and the ultimate fate of our entire universe. And you know, like any good cold case, the closer we look at the clues, the more baffling the mystery actually becomes. We're going to explore the absolute cutting edge of cosmology, tracking these staggering discoveries that have forced scientists to completely rethink reality itself.

Let's get started. Okay, let's dive right into this. If we can only see a fraction of our universe, what on earth is holding the rest of it together? See, when we look up at the night sky, we kind of just assume we're seeing the whole universe, right? But actually, we're only looking at a tiny, tiny fraction of it.

The central mystery that really kicked off modern cosmology is this massive problem of missing mass and energy. When astrophysicists looked out into the void, the math simply did not add up. If we're only seeing a sliver of the matter out there, what is keeping the whole shebang intact? Act one: the invisible universe.

To really understand this, we've got to jump back to the 1930s with an astronomer named Fritz Zwicky. He noticed something incredibly weird. Massive clusters of galaxies were behaving in ways that completely defied the known laws of physics.

By all accounts, a billion years after forming, those galaxy clusters should have just ripped apart and dispersed completely. But they hadn't. Something invisible was holding them together.

And this idea became absolutely undeniable thanks to the mind-bending work of Vera Rubin. Think about our solar system for a second. Planets close to the Sun, like Mercury, move incredibly fast.

And the further out you go, say out to Jupiter or Saturn, the speed drops. Well, that's exactly what we expected to see when looking at massive spiral galaxies like Andromeda. But Rubin found the exact opposite.

As you move away from the center of the galaxy, the rotation speed stays the exact same, and sometimes it actually goes up. The only logical explanation for this is a massive, totally invisible halo of dark matter surrounding the galaxy. We can't see it, light doesn't interact with it at all, but its gravity is literally the only thing keeping the galaxy from just flying apart.

Act 2. The Hubble Constant Crisis. Now this brings us to a massive headache for cosmologists, and that is measuring the expansion of the universe. We measure this using something called the Hubble Constant, which is in units of kilometers per second per megaparsec. I know, it sounds a bit like measuring in furlongs for Fortnite, but this weird unit is absolutely critical to understanding the age and the trajectory of our entire universe.

The big problem was that, depending on how we measured it, we kept getting completely different answers. When cosmologists used the WMAP satellite to measure the cosmic background radiation, they got one specific number. But when they used traditional methods, like looking at supernovas and standard stars, they got a totally different number.

And guys, this wasn't just a minor rounding error. It was a massive, statistically undeniable discrepancy. The two methods were just drifting further and further apart, creating a genuine full-blown crisis in cosmology.

So the crucial point here is that this crisis might actually, finally, be resolving. An astronomer named Wendy Friedman from the University of Chicago recently started measuring the expansion using what she calls red giant branch stars. And miraculously, her new measurements have bridged that gap.

Now, the satellite data and the star data agree to within an astonishing 5% margin. And let me tell you, for completely unrelated astrophysical phenomena, a 5% agreement- that is an absolute triumph. Act 3 – Cracks in the Big Bang. Now let's see how this builds into an even deeper mystery.

Because while we finally managed to pin down that expansion rate, two massive, glaring paradoxes began to emerge. And these paradoxes completely threatened the very bedrock of the Big Bang theory itself. The first one is called the Horizon Problem.

Imagine you're just sitting here on Earth. You look 14 billion light-years in one direction, and then you look 14 billion light-years in the exact opposite direction. The physical makeup and the temperature of those two distant horizons are perfectly, completely identical, but they are 28 billion light-years apart.

Because nothing moves faster than light, those two regions of space literally never had the time to communicate, mix, or even out their temperatures. So how on Earth did they become so perfectly regularized? The second crack in the Big Bang theory is the Flatness Problem. When cosmologists actually look at the size of the temperature splotches in the cosmic background radiation, they find that space is incredibly flat.

It follows basic Euclidean geometry – you know, the kind where parallel lines never meet – to a remarkably tiny 0.4% margin of error. Which means our universe aligns perfectly flat to about 1 part in 250 today. But here is where it gets really wild.

For the universe to be that flat today, what did it have to look like just 1 second after the Big Bang? Think of it kind of like aiming a rifle at a goose all the way across a massive bay. The further away that target is, the more absolutely flawlessly you have to aim. To hit a flatness of 1 part in 250 today, the aim 1 second after the Big Bang had to be accurate to a staggering 1 part in 10 to the 15th power.

That is 1 in a quadrillion. Let that sink in. And what if we wind the clock all the way back to 10 to the minus 37 seconds after the Big Bang? Well, the required precision jumps to 1 part in 10 to the 60th power.

That's a number so absurdly huge it honestly defies human comprehension. Just think about the existential weight of that for a second. Our very existence relied on this exact, mind-boggling precision.

There's just no way we simply got lucky. There had to be some sort of mechanism that forced the universe to be this perfectly precise. Act 4. Inflation.

The Cosmic Fix. Enter MIT physicist Alan Gouffe in the 1980s. Fascinatingly, he actually stumbled into the answer entirely by accident while he was searching for these bizarre isolated magnetic particles that mathematically should exist but just don't.

It's kind of like calling up Fisher Scientific to order 5 North Poles. It just doesn't make sense. But what he did stumble into is known as cosmic inflation, and this brilliantly illustrates how it works.

Gouffe proposed that the universe started as a tiny, microscopic seed about 10 to the minus 24 centimeters across. Inside that tiny seed, under incredibly specific conditions of Einstein's relativity, gravity briefly acted as a massive repulsive force. In just a fraction of a second, the universe underwent this insane hundred-fold doubling, inflating from smaller than a proton all the way up to the size of a marble.

And this single, incredibly violent event completely solves all of our Big Bang paradoxes. Why is the horizon totally uniform? Well, because before it inflated faster than light, everything was crammed together into that tiny seed, perfectly sharing the exact same temperature. And why is it so flat? Imagine an ant walking on a balloon.

If that balloon suddenly inflates to the size of the Earth, any curve that ant could see stretches out so much that the surface now appears perfectly, completely flat. And those slight variations in matter we see out in space? Those are just microscopic quantum fluctuations that got instantly frozen in time and blown up to massive macroscopic scales. Top particle physicists are incredibly confident in this theory.

When asked just how much they believed in inflation, Martin Rees actually said he'd bet his dog on it. Andre Linde said he was so convinced he'd bet his own life. And the legendary Steven Weinberg humorously summed the whole thing up by saying, I'm willing to bet Martin Rees' dog and Andre Linde's life.

I mean, you've got to love the confidence, right? Act 5. The Multiverse and the Final Mystery. Now, cosmic inflation opens up a really profound and honestly slightly terrifying door. Because if one tiny quantum seed can rapidly inflate into an entire universe like ours, there is absolutely no physical law preventing countless other seeds from doing the exact same thing, just sparking off their own universes left and right.

And this leads us straight to the multiverse and something called the Anthropic Principle. Now, you might be wondering, if there are so many universes out there, why are we so incredibly lucky to be in the exact one that allows galaxies and stars and humans to form? Well, as the Anthropic Principle points out, if this universe wasn't perfectly tuned to support life, we simply wouldn't exist to observe it in the first place. We're essentially just the lucky survivors of a massive cosmic lottery.

Now, what's really interesting about this next point is the staggeringly large number involved. Remember that dark energy we talked about that's driving the expansion of our universe? Well, when quantum physicists try to calculate exactly how much dark energy should exist in a vacuum, their math is off by a factor of 10 to the 120th power. It's universally considered to be the most embarrassing theoretical prediction in the entire history of physics.

If our universe actually had that much dark energy, everything would have blown apart before a single atom even had the chance to form. But here is exactly where the multiverse provides a pretty elegant answer. String theory predicts that there are about 10 to the 500th power possible substrates, or seeds, for universes.

With a number of possible universes that is unfathomably large, the odds of at least one universe having the exact perfect low-energy conditions of our universe aren't just possible; they're actually highly probable. It's bound to happen somewhere. And yet, this still leaves us with the ultimate question.

As cosmologists Alex Falinkin and Delia Prudivore point out, if the universe was born from nothing via a quantum loophole, it had to be governed by the laws of physics to do so. But where did those laws of physics come from? The whole idea of nothing suddenly transforming into something under the spell of abstract laws that existed before time and space even began- it's just deeply, deeply mystifying. Which brings us to a really beautiful concluding thought by Robert Jastrow.

He points out that for the scientist who has lived their whole life by their faith in the power of reason, the pursuit of the ultimate cosmic truth ends almost like a strange dream. As the scientist scales that final mountain of ignorance and pulls themselves over the highest rock, they are simply greeted by a band of theologians who have been sitting there for centuries. The universe is a beautifully complex place, and it seems the more we explain, the deeper the ultimate mysteries become.

So what do you think? Are we finally reaching the hard limits of physics, or are we just standing at the edge of a much, much stranger reality? Thank you so much for joining me on this explainer. Keep questioning the cosmos, and I will see you next time.