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WHY COSMIC EVOLUTION MATTERS

0:01–0:46

WELCOME TO SEASON TWO

Hi, I'm Emily Graslie, and welcome to season two of Crash Course Big History. In the first 10 episodes of Big History, we followed the history of the Universe from the Big Bang into the Deep Future. The theme of this season is "Why Does This Matter?"

As fascinating as the tale of 13.8 billion years is – from the vast cosmos to ancient life on Earth – one has to wonder why learning about this history is relevant to our own fleeting lives in this world. You don't exactly need to know about the Big Bang to fill out your tax returns.

But the reason we learn big history is the same reason we learn any history at all. History matures us, seasons our attitudes, and enriches our perspectives. If we read enough human history, going back thousands of years, we live a thousand lives. If we don't read history, we live only one.

0:46–1:43

BILLIONS OF YEARS

Let's take that thought one step further. Never mind the past 5,000 years of written history, or even the past 250,000 years that human beings have existed on the planet. By traversing the crash and thunder of the cosmos, to the tooth and claw of the evolutionary epic, we are transported across billions of years.

In a world that has learned so much about the cosmos, and a humanity that grows ever more closely interwoven in the 21st century, it pays to know the history of the Universe and our planet as well as we know, say, the past 200 years of our national histories.

Learn about Big History, and hopefully the world around you will appear as one long continuum to which you belong, indivisible and unbroken since the Big Bang, with an underlying pattern that unites it all. Human to human, and humanity to the Universe. It is a great leap forward into a wider world.

INTRO

1:43–2:16

EVOLVING VIEWS

In the Big Bang episode of Crash Course Big History, we learned about how our view of the Universe evolved in the early 20th century, leading into how our view of the Universe continues to evolve with every fascinating theory and new discovery.

One such theory is cosmic inflation, a theory about what happened a split second after the Big Bang.

It was originally devised in the 1980s by Alan Guth, to explain why the early Universe was so smooth and stable.

At approximately 10 to the power of negative 35 to negative 32 seconds, the Universe expanded rapidly from being about the size of a quantum particle, to the size of a grapefruit.

2:16–3:00

RAPID EXPANSION

This is stupendously fast. Even though the Universe is expanding fast today, it's still way slower than it was. If a grapefruit-sized universe expanded at the same speed as during cosmic inflation, in another split second, it would be the size of our current Universe, about 93 billion light years across.

If the early Universe had expanded at its slower, present day rate, gravity would have been too strong and sucked more clumps of matter and energy together, and the Universe would not be as evenly distributed. There would be huge inequalities, enormous heavy chunks of energy that are billions of light years across.

But the Universe expanded so fast during cosmic inflation that it was smoothed out, with no huge chunks of matter and energy anywhere. Instead we see a largely homogenous Universe with just a smattering of tiny unequal wrinkles that created stars.

3:00–3:57

TINY WRINKLES IN SPACE

And that's another reason why cosmic inflation was so important. When the Universe was still very, very small, at the quantum scale, tiny fluctuations were popping in and out of existence. These tiny blips of energy usually don't affect the physics of the larger world. But, during inflation, they were suddenly clear when the Universe became big, causing slight inequalities in matter and energy. These wrinkles created all the complexity that was to follow.

Without these unequal distributions of energy, there wouldn't have been enough energy for stars to burn, for supernovae to explode, for planets to form, for life to exist, and for us to be here.

We are the children of those tiny wrinkles, and the events that happened during cosmic inflation were the bedrock of the next 13.8 billion years. Know this part of the story, and you know where you came from, in the most extreme sense of the phrase.

A second theory holds that cosmic inflation may imply something curious about our Universe that has become known as the eternal inflation hypothesis, originally developed by Paul Steinhardt.

Let's go to the Thought Bubble.

3:57–4:28

THOUGHT BUBBLE

According to eternal inflation, the cosmic inflation that happened in a tiny, tiny sliver of a second may still be going on, for billions and billions of years, elsewhere in the Universe.

Our cosmic bubble, which is 93 billion light years across, is no longer in a state of eternal inflation.

The Universe continues to expand, and even accelerate in that expansion, but not quite at the breakneck speed of inflation.

The eternal inflation hypothesis implies that, within the sea of eternal inflation, new bubbles are popping up all the time. Other universes in a multiverse!

4:28–5:23

FUNDAMENTAL LAWS

Our fundamental laws of physics formed during inflation. It is highly conceivable that other sets of fundamental laws would govern these other universes, and these laws and rules would be completely foreign to our own.

And there is a staggering number of possible sets of physical laws, about 10 to the power of 500. That's a 1 with 500 zeros.

And that's not the number of other universes in a multiverse, but the possible set of rules on which an almost infinite number of universes could operate.

Even when the cosmic bubbles that come into existence in that vast inflationary sea operate on the same rules, they can have completely different outcomes. It's possible the outcomes are similar, but slightly different to ours.

1. A universe out there may exist where you watch this video approximately 30 seconds later.

2. Or a universe out there may exist where I was never born.

3. A universe may exist where everything is made out of diamonds or pizza or something completely different from atoms.

4. And many universes would exist without any stars or forms of complexity at all. Dead universes, where... everything is dead.

5:23–6:21

INFINITE VARIABLES

Thanks Thought Bubble. So, from here, physicists have postulated that the behaviour of Universes may operate under some form of "natural selection" like species do in nature - but for the cosmos.

By some variable or another, some universes make it into existence, and some do not. Or, more mind-bogglingly, that certain universes give rise to forms of extremely complex, intelligent, and powerful life that over time gain the ability to create and shape new universes, in a form of cosmic artificial selection. Sort of like how we breed different kinds of dogs or pigeons.

All of this is truly "out there" but that's how our view of the Universe continues to evolve. The Big Bang theory might have seemed preposterous to most scientists 150 years ago. Give us another 1000 years of scientific advancement, and who knows what our picture of the Universe may look like. As it is, eternal inflation implies that our cos-

mic bubble, already a massive 93 billion light years across, may actually be a very tiny bubble indeed, in a giant cosmic ocean known as the multiverse that is just teeming with other bubbles.

6:21–6:50

THE END?

As furiously as scientists are working at unravelling the beginnings of our Universe, it has remained a very curious question about how the Universe will "end" -- whatever end means when you're talking about something infinite.

For a long time, the most intuitive and prevailing theory was the Big Bounce.

That is, the expansion of the Universe continues to be slowed down by the force of gravity. Eventually, many billions upon billions of years from now, the Universe begins to contract. Gravity sucks everything, all matter, all energy, back into the singularity from which it sprang.

The immense pressure that forms that singularity forces everything out again in yet another Big Bang. And the whole cycle begins anew. Expanding, contracting, over and over and over. Hence the name: Big Bounce.

6:50–7:40

CIRCLE OF LIFE

And it makes logical sense, right? After all, what goes up, must come down. And there is another appeal to the theory. That of birth, death, and rebirth. A circle of life, not just for nature and the characters of the Lion King, but one for the entire Universe.

This is by far the most cheerful and pleasing scenario for the end of the Universe. And, alas, now the least likely one.

The Big Bounce presumes that eventually the expansion of the Universe will slow down. But, we now know it's not slowing down. It's accelerating. There are many hypotheses about why, one of the most prominent being the influence of the mysterious force of dark energy.

So, there are two more likely scenarios. The first is the Big Rip. If the expansion of the Universe continues to accelerate at an insanely fast rate, then the distances between things would become virtually infinite. This means the forces that hold the Universe together would be destroyed.

7:40–8:16

THE BIG RIP

The gravity that holds the stars in the galaxy together would be too weak and the Milky Way would fly apart. The planets would be ripped away from the Sun. Eventually the strong and weak nuclear forces that hold together atoms would be shorn apart as well. The scariest part of this scenario is how soon it could happen. Even within 10 or 20 billion years, which implies the Universe is roughly middle-aged.

The final scenario, and currently the most likely, is one that we covered in episode 10 of season one of Crash Course Big History:

Heat Death or the Big Freeze. In this scenario, the Universe continues to expand for trillions upon trillions of years till all forms of complexity exhaust themselves and break down.

Stars flicker out, matter dissolves back into energy, and the Universe becomes an evenly distributed weak ball of energy. The inequalities in energy created during inflation finally disappear.

8:16–9:03

THE BIG FREEZE

While not the most cheerful end to our story, it is decidedly less violent than the Big Rip. And it gives complexity in the Universe a great deal more time to exist - on the scale of trillions of years. Time and more research will tell whether the Big Rip or the Big Freeze is more likely.

Keep your eye on the experts as they continue to update you on the Universe's most terrifying weather forecast. Cloudy with a chance of absolute zero, or windy with a possibility of a vicious atom shredding later in the afternoon?

Finally, a last theory asks if the Universe is even real, or is it a simulation that our minds are inhabiting? This is actually the subject of some very interesting speculations by scientists and philosophers, like Nick Bostrom.

Just think about how far video games have come since the 1980s. Extend that rate of progress another 500 years. A simulated Universe isn't so fanciful on that scale.

9:03–9:54

A SIMULATED UNIVERSE?

According to Bostrom, one of the following statements must be true:

* Either such total simulations are impossible to create.

* Or, it is possible to create them but such an advanced society would put that computational power to better use.

* Or, they are possible to create, advanced societies do create them, and as a result there is a high likelihood we are currently living in a simulation rather than a base reality.

Why? Because, as Elon Musk puts it, given the rapid rate of technological advancements in virtual reality, if we are one day going to create those simulations anyway, the odds of us existing in the base reality that produces them really low.

But does a simulation reflect the outside Universe that created it? Or is the simulation a made-up, sort of fantasy reality? If it is the latter it would explain why physical laws only make sense to a certain point and why, when we get down to the scale of quantum physics, things seem so much more unpredictable.

9:54–10:59

THE GRAND UNFOLDING TALE

In a way, the pixels "blur" when we look that closely at the screen. However this may just be a convenient explanation to otherwise much more puzzling questions about quantum physics. It is, perhaps, a bit too convenient. But intriguing all the same.

In the 21st century, science has advanced by leaps and bounds. Humanity meanwhile is becoming more interdependent and in need of a common story. Our evolving view of the Universe continues to form the bedrock of that story, and as that view changes, so too will the view of ourselves as a part of the grand unfolding tale of 13.8 billion years.

Thanks for watching, see you next time.