The Big Bang: Crash Course Big History #1

Crash Course: Big History
https://youtube.com/watch?v=tq6be-CZJ3w
https://nerdfighteria.info/v/tq6be-CZJ3w

Hi. I'm John Green and this is Crash Course Big History, in which we'll be looking at the history of, like, everything. I'm talking about 13.8 billion years, from the big bang to now. I mean, in this series, we are literally going to attempt to tell you the story of what Douglas Adams famously called "life, the universe, and everything".

John from the past: Mr Green! Mr Green! That's not history. That's science, and science is for nerds!

John: Oh, me from the past! Things would be so much easier for you if you would just accept that you are, in fact, a nerd! And that's okay! I mean, look at this picture, dude!

Anyway, academics often describe history as like, all the stuff that's happened since we started writing things down, but they only start there because that's where we have the best information. And yeah, I think that the advent of writing was a huge deal, obviously, but as a start date for history, it's totally arbitrary! It's just a line we drew in the sand and said "okay, history begins now!"

In Big History, we're gonna start history when it really starts - at least, we think - at the creation of the universe, and we're gonna end that story where it ends - please let that be after I die! Well, I guess it will definitely be after I die, just- I want it to be a while after I die!

So we're even gonna terrify traditional historians by using physics to make some predictions about the future, and we're gonna end many trillions and trillions of years from now, when the universe itself, spoiler alert: dies. At least, in a manner of speaking.

(Crash Course Big History intro reel)

(1:34) Hank: Hey! I'm not John. If you're thinking we look a little bit the same, that's because we're brothers. I'm Hank. Anyway, if you wanna learn the 13.8 billion year history of the universe in the same amount of time that we usually cover the 238 years of American history, you're not gonna get the same resolution.

Of course, knowing the names and dates of American history is important, but we just can't do that in Big History. There are much broader historical questions in the story of the universe that can only be explored by zooming out to the ultimate scale. As you zoom out, you see a lot more of the picture. The details get a little fuzzy, but we quickly realize that history is everything. Cosmology, geology, biology, social sciences, literature, physics... Everything!

You might think that such a scale would be filled with way too much detail, but the amount of detail an answer requires, depends on the nature of the question. Some questions can only be explored by zooming out. That is what Big History does.

Speaking of zoomed out, this is Earthrise, one of the most famous photographs of all time. William Anders, an Apollo astronaut, took it in 1968. From the surface of another world, we see our planet as a little ball in space. No borders, no people, no buildings. Just oceans and clouds and continents being shined upon by the sun.

That sheer expansion of scale gives me perspective. It lets me imagine all the complexity of life on Earth, from the gasoline engine that powered my trip to the studio, to political instability in Nepal as part of a thriving, living, teeming mass of life floating in the emptiness of space.

(3:05) John: So what that photograph does for physical space, big history aims to do for everything. I mean, we wanna contextualize all of existence. We wanna outline the most powerful and important breakthroughs, the tremendous scale of existence and how we know what we know, and why we're sure we know it.

Alright, let's go to the thought bubble. So the universe is big. Like, really big. And it's also old. Like, 13.8 billion years old, which is enough years that there is no way to actually comprehend it. So let's just compress that age to 13 years, small enough that our puny brains can handle it.

On that timescale, the universe would have begun 13 years ago, in 2001. George W Bush had just been sworn in as president, most Americans on the internet were connecting to it with dial-up modems.

Right, so the first stars and galaxies would have formed 12 years ago, but seven and a half more years would pass until the Earth formed, about 4.5 years ago. Move a little bit up to four years ago - that's when the first single celled life formed on Earth. Then leap forward nearly three and a half more years before the first multi-cellular organisms in the Cambrian explosion...

What I'm trying to explain is that all complex life on Earth is a fairly recent development. Like, on this scale, the dinosaurs went extinct about three weeks ago - roughly the last time I changed my Facebook status.

Humans and chimpanzees split from their last shared ancestor about three days ago! The first homo sapiens emerged fifty minutes ago, roughly the last time I checked my email. We left Africa 26 minutes ago. The American-Indians reached the Americas 6 minutes ago - roughly the last time I checked my Twitter.

We invented agriculture 5 minutes ago. Ancient Egypt? 3 minutes ago! The Black Death? 24 seconds ago. The Industrial Revolution - 6 seconds. World War One, 2 seconds. The Cold War, the first man on the moon, your birth, the internet, the Big Mac? All within the last second.

But in many other ways, complex life and humanity are exceptional. Thanks, thought bubble! Also exceptional, by the way, the Mongols! (a clip of the Mongols)

(5:03) Hank: Okay, let's begin at the beginning! The big bang!

John: Hank, wait a second! Woah, woah, woah, woah, woah. I- I don't understand how we know that the big bang is really the beginning. Like, what happened before the big bang?

Hank: Well. Okay. Uh... Theoretical physicists say that space and time are not two different things. They are two expressions of one thing - space-time. And space-time was created by the big bang, thus time didn't exist before the big bang, so it doesn't make much sense to ask what happened before it. There was no "then", then!

Of course, this, like many ideas in cosmology, doesn't really make any sense to our puny human brains. It's largely beyond our comprehension, rather like explaining color to a blind person. We know that it's true because the math works and it explains our observations so elegantly, but it's so far outside of how we directly perceive the world, that I don't think it's something even the most genius physicists are able to imagine.

But yeah, if you're gonna do a chronological study of the universe, the creation of time is probably a pretty good place to start the story.

(6:04) John: So the big bang wasn't something that happened inside the universe, nor did it expand into some kind of void. It was literally the moment when both time and space were created. The thing that was banging was the universe itself. It was expanding from an unimaginably tiny point to an unimaginably large universe, unimaginably quickly.

"Unimaginable" is basically the subtitle to the story of the big bang, but then again, it's also kind of the subtitle to everything else in big history.

I mean, I can only do this occasionally, but sometimes you look outside and you're like "oh, my goodness! This is nuts! How did we get trees?" Needless to say, we will be talking about that.

Anyway, the universe is a hard-worker, and it got most of the heavy lifting done in those first few seconds. For comparison, it takes me about twenty minutes after I wake up for me to even get myself into a standing position. But the universe is somewhat more efficient.

In the barest fraction of the first second, the universe inflated from something many, many, many times smaller than an atom to about the size of a grapefruit. Like, think of it this way: in much less than the blink of an eye, if it'd originally been the size of a tennis ball, it would have inflated to over ninety billion light-years across.

This inflation theory has been well backed-up by mathematics for a long time now, but it has recently received some staggering new support from the BICEP project at the South Pole, which sadly has nothing to do with my "guns".

Ten seconds after the big bang, the universe had expanded enough that the normal rules of the universe, with atomic forces and gravity and electromagnetism that we know and love today, were already in charge. All of the anti-matter created in the big bang had combined with matter and annihilated itself, leaving behind only one billionth of the matter created in the big bang - and that billionth is everything! And I mean everything. Every grain of sand, every blueberry you will ever eat, every star that you will ever see - everything!

We've already tried to understand how big a billion is, but just pause to think about that - everything! Everything - is one billionth of the matter created in the big bang. *mind-blown action*

The first law of thermodynamics is that matter and energy cannot be created or destroyed. Everything we have now, we had then. The matter that makes up your body right now has been around since those moments 13.8 billion years ago. It's simply changed form.

After just three minutes, the universe was cool enough that the nuclei of atoms started forming - just hydrogen and helium back then, the two simplest elements - keep those two in mind, however, because it turns out, if you take a bunch of hydrogen and you wait like, several billion years, you might just grow yourself some humans!

Let's remember: at this time, the universe was still very, very hot. I don't wanna use the word "unimaginable" too often, but it was unimaginably hot! The universe remained like an uber-hot sea dominated by radiation, but then luckily, it simmered down to a balmy 5,000 degrees Fahrenheit about 380 thousand years after the big bang, allowing matter and radiation to separate.

And remember, matter is just a more congealed form of energy. I mean, you are a somewhat firm bag of energy. In my case, not that firm.

So anyway, at 5,000 degrees Fahrenheit, radiation was finally able to move freely through the universe, and we see that radiation today as the end of the Dark Ages that followed the big bang, and the beginning of a brilliant flash that we call Cosmic Background Radiation, which is a great name for a band.

Physicists call it the fingerprint of the universe and it's one of the most important pieces of historical evidence we have for the big bang, because CBR is everywhere.

Tune your radio to a frequency that doesn't have a station - a portion of the static you hear is actually that cosmic background radiation being picked up by your radio. So you can literally hear the universe in its infancy!

(9:42) Hank: Sometimes it can be tricky to know what's true, especially when we're talking about stuff that happened so far in the distant past. That is why we created science, that elegant system for sorting out the facts from the fertilizer.

So just using your limited human senses, you might come to the same conclusion as 19th century scientists, that the universe is static, eternal and infinite... But then, using our minds, if the universe is infinite and contains infinite stars and it has always existed, then the night sky, and the day-time sky for that matter, would literally be filled with stars - so much that day and night would be indistinguishable! This is clearly not the case, so something must be amiss.

The universe must either be not static, not infinite or not eternal. So which is it? You know how when an ambulance drives towards you, the sound-waves are compressed and the siren sounds higher pitched, and as it speeds away, the waves are stretched out and the pitch is lower? It's the Doppler effect.

Well, here's another name you've heard. Edwin Hubble. He realized that light does the same thing. Galaxies and stars moving away from us have their light stretched out, making it more red, and stars moving toward us have their light compressed, making it more blue. Combined with the work of Henrietta Leavitt, which allowed us to accurately estimate how far away stars are, Hubble was able to determine that stars, on the whole, are flying away from each other.

He discovered that the most remote objects in the sky were all red-shifted and were actually other galaxies beyond the milky way, moving away from us. From here, he built upon the work of Belgian Catholic priest Georges Lemaitre, who hypothesized that the universe began at a single point. Big bang cosmologists wanted proof though. They knew that the amount of radiation released by the big bang would be massive, and they wanted to see it.

It wasn't until the 1960s that it was found accidentally, by two guys working on an antenna at Bell Laboratories in New Jersey. They were trying to eliminate all the background noise from an extremely sensitive radio antenna, but they found this faint hum coming from every direction.

They tried everything they could to get rid of it, including murdering the pigeons that kept pooping on the antenna - kinda sad, but those pigeons - they gave their lives for one of the most profound discoveries in modern science. A conversation with a local radio astronomer lead them to show their findings to an astronomer at Princeton, who confirmed the existence of what had been predicted for years.

The final piece of that big bang puzzle is that we can see it. Light has a speed. When we look at the sun, we're seeing the light that left it eight minutes ago, but if we look at something that's 13.8 billion light-years away, we're seeing the stuff that happened 13.8 billion years ago! That radiation has been traveling since the very beginning of the universe.

Not only can we tell very clearly that there was just nothing there before that, we can now study that radiation to learn the sequence of events of the big bang. We can also see that the chemical composition of the early universe is what we'd expect to see - a lot

of hydrogen, a lot of helium and a tiny pinch of lithium. The rest of the periodic table had to wait for the fiery furnaces and the bellies of stars to be created... But more on that, next episode!

(12:40) John: As far as we've come in the past century in crafting a history of the universe, there are still many things cosmologists have yet to discover. For instance, the universe behaves as if there's a bunch of matter in it that we can't see or detect. Galaxies' gravitation is affected by this matter, but it's otherwise completely invisible to us. Physicists call it dark matter, but we have no idea what it is! But as in any historical endeavor, new discoveries will alter the story in future years, so expect the big histories of ten or twenty years from now to look very different from today's.

But this isn't discouraging, because like, knowing everything would be boring! There's a lot left to discover, and at the current pace of scientific inquiry, many of those amazing discoveries will await us in our lifetime! Or at least in your lifetime.

(13:24) Hank: Whether it be World War Two or the life of Abe Lincoln, all histories ultimately start with the big bang. Yeah, it would be silly to start your typical World War Two textbook with the big bang, but it would be about a hundred trillion, trillion times more ridiculous to say the big bang - the mother of all historical events - was not history.

And that's why big history reaches into the lives of every person on this tiny speck of dust we call home, regardless of nation, class or creed, and forms our common story. See you next time!