TedEd-04

The Death of the Universe

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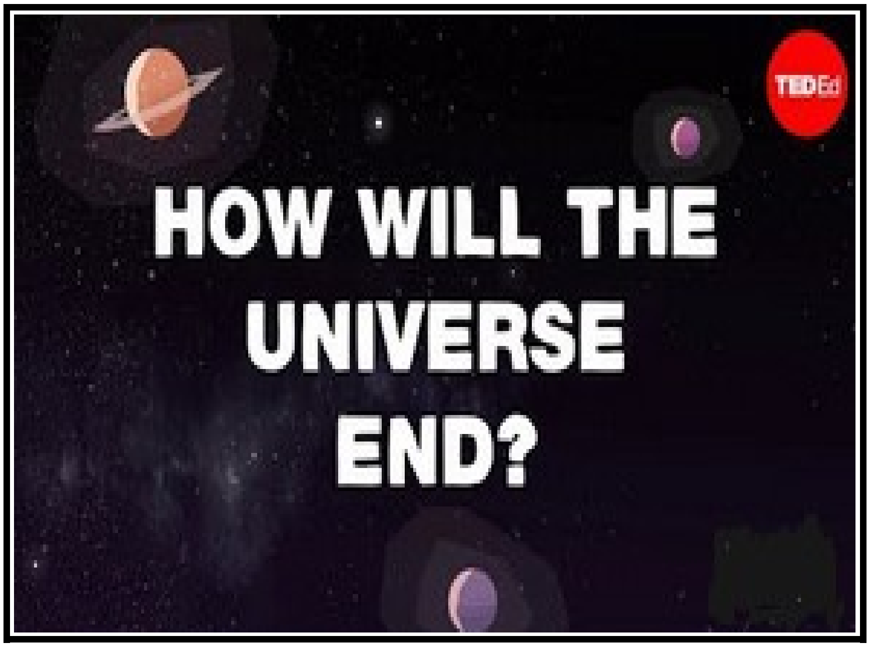

Looking up at the night sky, we are amazed by how it seems to go on forever. But what will the sky look like billions of years from now? A particular type of scientist, called a cosmologist, spends her time thinking about that very question. The end of the universe is intimately linked to what the universe contains. Over 100 years ago, Einstein developed the Theory of General Relativity, formed of equations that help us understand the relationship between what a universe is made of and its shape. It turns out that the universe could be curved like a ball or sphere. We call this positively curved or closed. Or it could be shaped like a saddle. We call this negatively curved or open. Or it could be flat. And that shape determines how the universe will live and die. We now know that the universe is very close to flat. However, the components of the universe can still affect its eventual fate. We can predict how the universe will change with time if we measure the amounts or energy densities of the various components in the universe today.

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So, what is the universe made of? The universe contains all the things that we can see, like stars, gas, and planets. We call these things ordinary or baryonic matter. Even though we see them all around us, the total energy density of these components is actually very small, around 5% of the total energy of the universe. So, now let's talk about what the other 95% is. Just under 27% of the rest of the energy density of the universe is made up of what we call dark matter. Dark matter is only very weakly interacting with light, which means it doesn't shine or reflect light in the way that stars and planets do, but, in every other way, it behaves like ordinary matter - it attracts things gravitationally. In fact, the only way we can detect this dark matter is through this gravitational interaction, how things orbit around it and how it bends light as it curves the space around it. We have yet to discover a dark matter particle, but scientists all over the world are searching for this elusive particle or particles and the effects of dark matter on the universe. But this still doesn't add up to 100%. The remaining 68% of the energy density of the universe is made up of dark energy, which is even more mysterious than dark matter. This dark energy doesn't behave like any other substance we know at all and acts more like anti-gravity force. We say that it has a gravitational pressure, which ordinary matter and dark matter do not. Instead of pulling the universe together, as we would expect gravity to do, the universe appears to be expanding apart at an ever-increasing rate. The leading idea for dark energy is that it is a cosmological constant. That means it has the strange property that it expands as the volume of space increases to keep its energy density constant. So, as the universe expands as it is doing right now, there will be more and more dark energy.

Dark matter and baryonic matter, on the other hand, don't expand with the universe and become more diluted. Because of this property of the cosmological constant, the future universe will be more and more dominated by dark energy, becoming colder and colder and expanding faster and faster. Eventually, the universe will run out of gas to form stars, and the stars themselves will run out of fuel

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and burn out, leaving the universe with only black holes in it. Given enough time, even these black holes will evaporate, leaving a universe that is completely cold and empty. That is what we call the heat death of the universe. While it might sound depressing living in a universe that will end its lifetime cold and devoid of life, the end fate of our universe actually has a beautiful symmetry to its hot, fiery beginning. We call the accelerating end state of the universe a de Sitter phase, named after the Dutch mathematician Willem de Sitter. However, we also believe that the universe had another phase of de Sitter expansion in the earliest times of its life. We call this early period inflation, where, shortly after the Big Bang, the universe expanded extremely fast for a brief period. So, the universe will end in much the same state as it began, accelerating. We live at an extraordinary time in the life of the universe where we can start to understand the universe's journey and view a history that plays itself out on the sky for all of us to see.