OP-EDS

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Are we finally on the verge of discovering why we are here?


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Why are we here? This is one of the questions that has fascinated philosophers and scientists alike. Physicists have made astonishing progress in combining knowledge from different fields to reverse engineer how the universe evolved into the dynamic world of matter we see around us. Recently, this progress has stumbled upon an unexpected puzzle: Why do we only see a world of matter?

We have known for nearly a century that another type of substance exists: antimatter. This mysterious substance looks exactly like matter, only it explodes when it is in contact with matter. In fact, if I met my anti-self, he would look the same until we shook hands. At that point there would be an explosion that

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would release the equivalent energy of a billion tons of exploding TNT or eating a trillion tons of sugar! The puzzle of the lack of antimatter has become more existential over the last few decades as we have learned more about what we are made of and what the world looked like seconds after its birth.

Everything we know says that matter and antimatter should be produced in equal amounts. Yet we can tell, by observing light from a million years after the universe was born, that for every 10 billion antiparticles produced in the primordial soup, 10 billion and one particles were produced. This difference, this slight imbalance, may seem small, but it was enough of a difference to save us from complete annihilation. In modern cosmology, the question of "Where is all the antimatter?" has become equivalent to "Why are we here?" So far, nothing in our knowledge provides an answer!

At this point, one might appeal to divine intervention — maybe God just said, "Let there be 10 billion and one particles for every 10 billion antiparticles!" But there would be a catch — we know that before such a difference between matter and antimatter existed, there was almost certainly a period when the universe violently and rapidly expanded, diluting just about every feature of the universe to nonexistence. This period is known as "inflation," and it is a giant cosmic eraser. Even if a divine command was uttered, it was undone a fraction of a second later! Our very existence proves that there must be new laws of physics waiting to be discovered.

This amazing puzzle has inspired scientists all over the world. We know of many possible answers to this baffling question, but two main ideas have attracted the most attention. The first idea postulates that when the universe was about a billion times hotter than the center of the Earth, it started to boil. Bubbles formed, and inside these bubbles, both particles and antiparticles had a mass, whereas outside they were massless. The particles and antiparticles had slightly different chances of passing through the bubble wall, and a tiny difference between matter and antimatter was created.

The second idea involves the lightest particles in the universe, neutrinos, which are a billion times lighter than an electron. This idea theorizes that neutrinos have heavy friends known as steriles. These neutrinolike particles that spin in the opposite direction were initially proposed as the simplest way to explain how neutrinos have a mass at all. It was found that if these steriles exist, however, they like to decay into antineutrinos slightly more often than neutrinos.

Until now, physicists have believed that the first explanation was testable, while the second was not. A giant machine in Switzerland known as the Large Hadron Collider is testing whether the physics needed to make the universe boil really exists. The steriles, on the other hand, have to be at least a million times heavier than anything that can be produced at the Large Hadron Collider.

But the game changed with the discovery of gravitational waves. The universe is no longer see-through to light when we try to look earlier than its millionth birthday — an impenetrable veil is created by the extreme density and heat of the old universe. Yet, the universe is completely transparent to gravitational waves, right back to when the universe was hot enough for these steriles to be common and ensuring our safety from complete annihilation.

Scientists from Berkeley, Japan and Vancouver, Canada (including myself) have shown that these steriles can produce a bunch of tiny tubes where they have no mass, known as "cosmic strings." When this network of strings tries to simplify itself, it produces ripples of gravitational waves. The size of these ripples are big enough to be seen today for the entire range of masses these steriles can have! Most exciting of all, we have shown that one does not have to be lucky for us to see these ripples — they are consistent across space-time.

We categorized all the ways in which the steriles can get a mass and more than half of these ways produced ripples. We also predicted the range in size that these ripples can have, using the fact that the steriles have to have specific properties to explain our existence.

The world is now in a competition to see gravitational waves in many different ways through many different experiments. This race involves the U.S., Europe, China and Japan as major players that have all proposed exciting experiments, and some experiments even have funding and launch dates. We, therefore, compared the sensitivity of proposed experiments that search for gravitational waves

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with the ripples produced when we were saved from complete annihilation. Between all of these international efforts, nearly the entire range of masses that these steriles can have can be seen over the next few decades.

It is, therefore, more likely than not that these ripples truly exist and will be detectable by proposed experiments. In other words, we would have to be bitterly unlucky to not find the answer to why we are here within our lifetime! The range of time that it will take for these experimental results to come through is a couple of decades. It is the perfect time for those thinking about starting a career in physics to join in on finding the answer to the millennial-old question of how we got here.

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