Could the Big Bang have been a quick conversion of antimatter into matter?

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If matter and antimatter repel each other, the quick conversion of one into the other inside a supermassive black hole may look like a Big Bang. Image credit: NASA

(PhysOrg.com) -- Suppose at some point the universe ceases to expand, and instead begins collapsing in on itself (as in the “Big Crunch” scenario), and eventually becomes a supermassive black hole. The black hole’s extreme mass produces an extremely strong gravitational field. Through a gravitational version of the so-called Schwinger mechanism, this gravitational field converts virtual particle-antiparticle pairs from the surrounding quantum vacuum into real particle-antiparticle pairs. If the black hole is made from matter (antimatter), it could violently repel billions and billions of antiparticles (particles) out into space in a fraction of a second, creating an ejection event that would look quite

similar to a Big Bang.

Dragan Slavkov Hajdukovic, a physicist on leave from Cetinje, Montenegro, currently working at CERN in Geneva, Switzerland, emphasizes that he has no idea if this scenario occurred 13.7 billion years ago or not. But in a recent study published in *Astrophysics and Space Science*, he has described a mechanism that can convert matter into antimatter (or vice versa) that results in a cyclic universe that is successively dominated by matter and antimatter. In this scenario, when a matter-dominated universe collapses, an antimatter-dominated universe emerges, and the cycle continues indefinitely.

Cyclic universe

The idea of a cyclic universe is not new. As Hajdukovic notes in his paper, in 1922 cosmologist Alexander Friedmann noticed that Einstein's theory of general relativity is compatible with the framework of a cyclical universe. More recently, cyclic models have included loop quantum gravity, braneworld theories, and other "Big Bounce" models. However, unlike Hajdukovic's scenario, in all of these models, all cycles are dominated by matter. As Hajdukovic explains, he is not offering a new cyclic model of the universe, but simply a mechanism that could, in principle, have allowed the transition from a matter-dominated universe to an antimatter-dominated universe, and vice versa.

To begin, the mechanism must allow for the creation of particle-antiparticle pairs from the quantum vacuum. Although the quantum vacuum is completely empty of particles or anything else, there do exist short-lived virtual particle-antiparticle pairs that pop in and out of existence, as allowed by the uncertainty principle. To explain how these virtual particle-antiparticle pairs can become real ones, Hajdukovic turns to the Schwinger mechanism, which says that an electric field stronger than a critical value can create real electron-positron pairs from the

quantum vacuum. He proposes that, in a gravitational version of the Schwinger mechanism, gravitation could create both charged and neutral particle-antiparticle pairs from virtual particles.

The mechanism also relies on the hypothesis that matter and antimatter repel each other. This repulsion could be of gravitational origin (as in the idea of antigravity) or non-gravitational origin. Here, Hajdukovic imagines the existence of a matter-antimatter repulsion that is significant only at short range; specifically, inside a black hole's event horizon, or smaller than the Schwarzschild radius. Immediately after the gravitational Schwinger mechanism produces particle-antiparticle pairs, the repulsion force would cause a black hole to violently repel the opposite particle type. The result would be the conversion of nearly all matter into antimatter (or vice versa) in a very short time that depends on the size of the black hole.

Through calculations, Hajdukovic shows that the amount of matter that can be converted into antimatter (or vice versa) in one second could be up to 10^{128} kg, which is several orders of magnitude greater than the entire mass of the universe, about 10^{53} kg. If correct, it would mean that all of the matter in the universe could be converted into antimatter in a fraction of the Planck time.

Such a scenario would have multiple implications. For one thing, it would prevent the universe from collapsing into a singularity by requiring a minimal size of about 40 orders of magnitude greater than the Planck length, or on the order of kilometers. This is the size of the universe after cosmological inflation, suggesting that inflation and everything that came before it in standard cosmology (such as numerous phase transitions) never occurred.

The scenario also offers a simple explanation for matter-antimatter asymmetry: the reason that our present-day universe is dominated by

matter instead of antimatter is that the previous universe was dominated by antimatter. And the next one will, once again, be dominated by antimatter.

Beyond Standard Cosmology

Whether or not this scenario is accurate, Hajdukovic explains that it's important to investigate alternatives to the standard model of cosmology, given its limitations.

“Apparently, our best physics [Einstein’s General Relativity and the Standard Model of particle physics] is insufficient to explain a series of observed phenomena in astrophysics and cosmology,” he said. “In addition to the well-established physics, the standard model of cosmology assumes (a) the existence of mysterious dark matter and dark energy which represent more than 95% of the content of the Universe, and (b) the existence of two mechanisms (of unknown nature) to assure inflation and matter-antimatter asymmetry in the primordial universe. Hence, the Standard Cosmology is based more on hypotheses than established physics. It is a very unsatisfactory situation.

“Contrary to it, my work is an attempt to understand astrophysical and cosmological phenomena in the framework of the established physics, without invoking unknown forms of matter-energy and unknown mechanisms for inflation and matter-antimatter asymmetry.”

In a handful of other recent papers, Hajdukovic has shown that understanding the universe in this way may indeed be possible. For instance, in his paper titled “Is dark matter an illusion created by the gravitational polarisation of the quantum vacuum,” he obtains a “striking equation” in agreement with observations and without invoking dark matter.

He added that it may be possible to test one of the basic components of these ideas, namely, detecting signatures of the gravitational repulsion between matter and antimatter. The most direct test is the AEGIS experiment at CERN, which is designed to measure the gravitational acceleration of antihydrogen in the gravitational field of the Earth. Another test could come from the Ice Cube Neutrino Telescope at the South Pole, which could observe antineutrinos coming from supermassive black holes in the center of the Milky Way and Andromeda galaxies.

"If you ask me what is the key for the understanding of the universe, I would say the quantum vacuum together with (for the moment hypothetical) gravitational repulsion between matter and antimatter," Hajdukovic said. "One simple key, instead of four mysterious keys in Standard Cosmology. My answer may be wrong, but if it is correct it would radically change theoretical physics, astrophysics and cosmology."

More information: Dragan Slavkov Hajdukovic. "Do we live in the universe successively dominated by matter and antimatter?" *Astrophys Space Sci* (2011) 334:219-223. DOI: 10.1007/s10509-011-0754-2