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LIFE & WORKIDEASWILCZEK'S UNIVERSE

Accounting for a Wrinkle in Time

In most cases, physics follows the same rules whether things run forward or backward—but not quite always

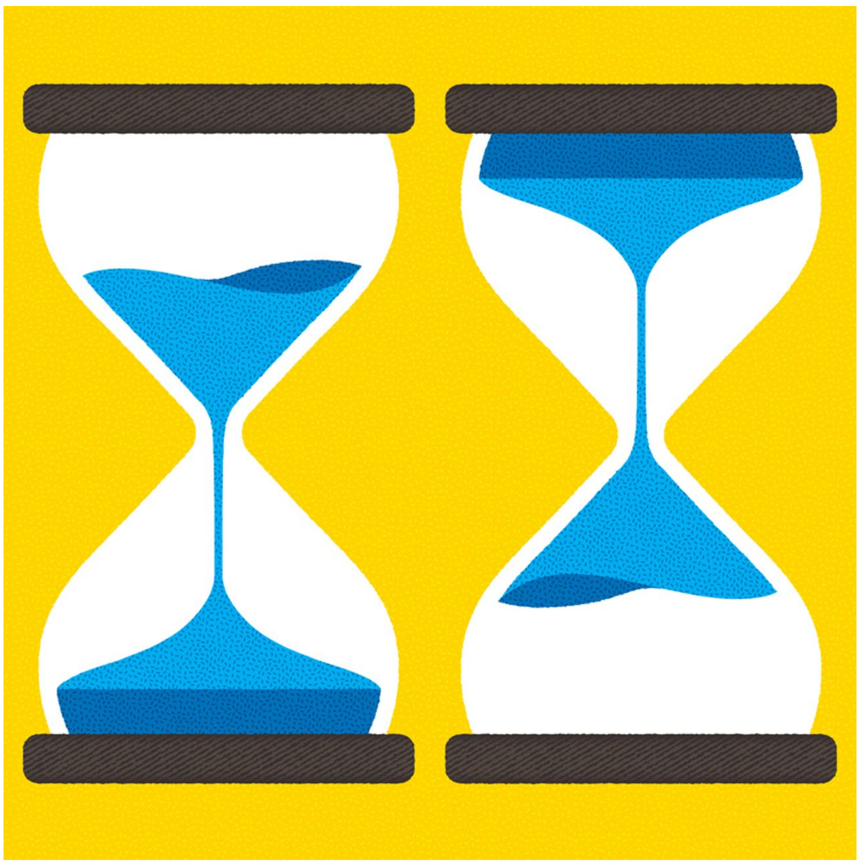

ILLUSTRATION: TOMASZ WALENTA

By Frank Wilczek

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Nobel Prize-winning physicist Frank Wilczek explores the secrets of the cosmos. Read previous columns here.

Since the dawn of recognizably modern physics in the late 17th century, our understanding of nature's basic operating system has undergone major expansions and renovations. It got vastly more detailed and powerful. We brought in electromagnetic fields, space-time curvature and the quantum revolution. Through all that growth and tumult, a simple and weirdly beautiful, yet enigmatic and seemingly gratuitous, feature of the laws remained intact. It is known as time reversal symmetry. Time reversal symmetry—or T for short—says that if you take a movie of events in the physical world and run it backward, what you see will obey the same basic laws.

Newton's laws of motion and gravity, Maxwell's equations of electrodynamics, Einstein's relativity theories and the Schrödinger and Dirac equations that implement quantum theory all obey that principle. So did everything scientists observed in the physical world—until 1964. That year James Cronin, Valentine Fitch and collaborators at Brookhaven National Laboratory on Long Island discovered that some subtle features of the behavior of highly unstable particles called K mesons would look a little different in a time-reversed movie.

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Richard Feynman's famous "Lectures on Physics," written shortly before, eerily anticipated this development. He cited a gate in Neiko that is often described as Japan's most beautiful. Its delicate, otherwise symmetric ornamentation has one small element carved upside down. "The story is that it was carved upside down so that the gods will not be jealous of the perfection of man," he wrote. "We might like to turn the idea around and think that the true explanation of the near symmetry of nature is this: that God made the laws only nearly symmetrical so that we should not be jealous."

There might be a more conventional explanation. In 1973 the Japanese physicists

Takuru Kobayashi and Toshihide Maskawa showed that for most processes time-reversal symmetry follows unavoidably from three other, deeper principles—relativity, quantum mechanics and the high symmetry that is central to our theories of the universe's four fundamental forces. The Kobayashi-Maskawa theory also showed why T fails in the sorts of processes that Cronin and Fitch studied. But the theory is not quite complete; T works a little better, in more instances, than Kobayashi and Maskawa described.

A glorious conclusion to this saga might be emerging. In 1977 two American physicists, Roberto Peccei and Helen Quinn, showed that including further symmetry in our equations can close the remaining gap in answering where T works and doesn't. Steven Weinberg and I discovered independently that implementing this idea brings in a wholly new kind of particle. I named this theoretical particle the axion, after a laundry detergent, because it would clean up a nasty problem. Later work by myself and others showed that axions produced in the Big Bang would have the right properties to answer another mystery: They could be the so-called "dark" matter whose existence is, so far, only inferred from its gravitational influence on ordinary (visible) matter.

Axions are predicted to be hard to detect, but research physicists around the world are designing and building instruments that could be up to the job. If so, the ultimate explanation for exceptions to T would be different from Feynman's joke and more in line with one of Einstein's: "Subtle is the Lord, but malicious He is not!"

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