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LIFE & WORKIDEASWILCZEK'S UNIVERSE

A Particle That May Fill 'Empty' Space

Discovered 10 years ago, the Higgs particle promises to unlock secrets of how the universe works

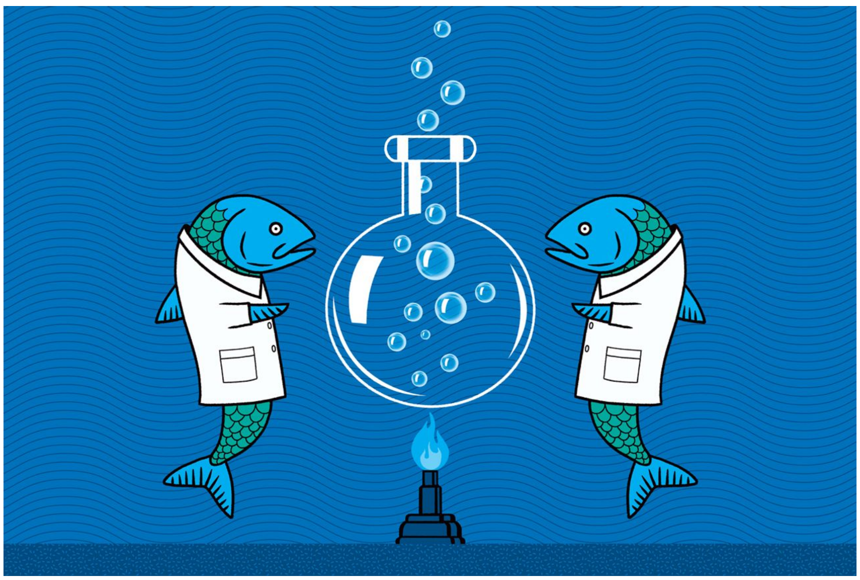

ILLUSTRATION: TOMASZ WALENTA

By Frank Wilczek

Dec. 29, 2022 at 1:05 pm ET

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

This year marks the 10th anniversary of the discovery of the Higgs particle. Now we can see it in perspective.

To understand its significance, imagine an ocean planet where intelligent fish evolve and start to make theories of how things move. They do experiments and deduce equations but it is a messy hodgepodge, because the fish, taking their ever-present environment for granted, think of their ocean as "empty space."

After decades of work, though, some realize that by postulating that "empty space" is a medium—ocean—that has mass and motion of its own, you can account for everything using simple, elegant laws (namely, Newton's laws). Next, the fish start to wonder what their hypothetical ocean is made of. They boil some ocean, do some sophisticated spectroscopy, and ultimately identify water molecules. Imagined beauty guided them to concrete truth.

A broadly similar story played out here on Earth. When physicists in the early 20th century discovered the subatomic "weak force" that governs many transformations of nuclei and particle decays, they first arrived at imperfect equations to try to describe how it works. Those equations postulated particles called "W," which spur the weak force in the same way that photons spur the electromagnetic force. Unfortunately, consistent application of those equations predicts that W particles, like photons, should have mass equal to zero, which they don't.

While all other known particles fit beautifully into an overarching 'grand unified' theory, the Higgs particle remains a stranded orphan.

A seemingly far-removed phenomenon, superconductivity, suggested a way out. As first envisioned in 1935 by the physicist brothers Fritz and Heinz London, photons acquire non-zero mass inside superconducting material. That mass modifies the equations in just such a way that they correctly describe how electrodynamics works inside superconductors. In 1957, John Bardeen, Leon Cooper and J. Robert Schrieffer showed that electrons inside superconductors condense into a cohesive ocean of two-electron molecules that impedes the free motion of photons and renders them a bit sluggish, in effect giving them mass.

Now we come to the role of Peter Higgs. In 1964 he, and independently Robert Brout and Francois Englert, had the imagination to suggest that W particles have their mass because what we perceive as "empty space" is no emptier than the ocean of our imagined intelligent fish. As far as W particles are concerned, "empty space" is a fluid medium: a super-duper-superconductor.

That audacious hypothesis made the equations consistent. But what makes up this medium, invisible yet pervasive, that impedes the free motion of W particles and gives them their mass? No combination of the known ingredients of matter was up to the job.

To address that challenge, physicists banged protons together, concentrating energy into a very small volume, hoping to break off little pieces of the fluid. On July 4, 2012, two experimental collaborations, each involving hundreds of researchers at the Large Hadron Collider near Geneva, presented evidence that a new particle, named after Higgs, is the main constituent of this cosmic super-duper-superconductor.

Ten years of intense experimentation and scrutiny have confirmed that the Higgs particle has the right properties to make the super-duper-superconductor we inhabit. Yet it remains an enigmatic outlier. While the influence of Higgs particles gives mass to other particles, its own mass remains totally mysterious. And while all the other known particles fit beautifully into an overarching "grand unified" theory, the Higgs particle remains a stranded orphan. Those loose ends suggest that there should be more to the story, and that closer study of the Higgs particle might open a portal into new and otherwise inaccessible worlds. Thus, the Higgs particle is 10 years young.

Appeared in the December 31, 2022, print edition as 'A Particle That May Fill 'Empty' Space'.