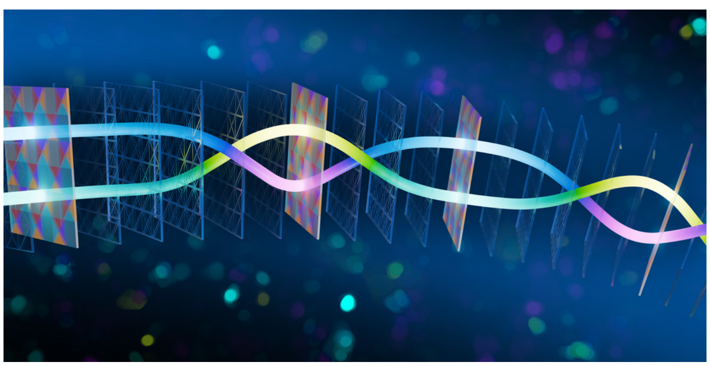
# Strange Swapping Behavior Defines New Particle Candidate

**Researchers predict the existence of a class of particles that behave differently from those already known.**

By **Katherine Wright**

The list of fundamental particles has a possible new entry, according to theoretical predictions from Zhiyuan Wang of the Max Planck Institute for Quantum Optics, Germany, and Kaden Hazzard of Rice University, Texas [**1**]. The proposed particle, termed a paraparticle, has behaviors distinct from those of fermions and bosons, the fundamental particles that make up known matter. Wang and Hazzard predict that these new particles could appear as quasiparticles in condensed-matter systems or, more speculatively, as elementary particles in high-energy physics experiments. "There was a belief that all fundamental particles must be fermions or bosons. Here we show there could be something beyond that," Wang says.

Take two bosons, such as two photons, and swap their positions and all the other properties of the particles—their mass, momentum, and spin—should be unchanged. The same behavior is observed when changing the positions of fermions, such as electrons, except that the overall wave function that describes the particles takes on a minus sign. By contrast, paraparticles have extra properties—a set of internal degrees of freedom—that should take on new values when two of them are swapped. These extra properties can be imagined as an internal "arrow" that points in different directions, depending on the internal quantum state of a paraparticle.



An artist's rendition of two paraparticles switching places. When the particles switch positions, their internal quantum states change. Returning the particles to their original positions restores the particles' internal quantum states to their original values.
**Credit: M. Norton/Rice University.**

The concept of the paraparticle was first mentioned 100 years ago by Wolfgang Pauli of exclusion-principle fame. But, Wang says, the idea was not taken seriously until the 1950s when theorists began to explore whether more complex particles than bosons and fermions might exist. However, attempts to develop concrete models failed—the particles they predicted all ended up behaving like fermions and bosons—and by the 1970s the idea of paraparticles had been lost by the wayside. "For the last 50 years, paraparticles have basically been forgotten," Wang says.

Previous attempts at modeling paraparticles used quantum field theory. Wang and Hazzard also followed this route but started with a different mathematical formalism called the Yang-Baxter equation. This equation shows up in exactly solvable statistical-mechanics models, where it acts as a consistency check in particle scattering scenarios, preserving the momentum of the particle while changing its internal quantum state.

Wang says he hadn't initially been searching for a theory of paraparticles. Rather, he was working on solutions to some abstract mathematical problems when it popped up by accident. “I found a curious solution to the problem I was working on, and when I interpreted it physically, paraparticles appeared,” he says.

Wang notes that paraparticles are not the only type of particle to exhibit swap-dependent internal quantum states. Anyons, quasiparticles seen in some two-dimensional condensed-matter systems, can also display this behavior. However, unlike these anyons, paraparticles can exist in all dimensions, not just two. Also, the internal states of two paraparticles that have had their positions swapped twice—that is, both have come back to their initial positions—will return to their original value. The internal states of two swapping anyons, by contrast, do not reset to their original values.

Wang says that the swapping behavior of paraparticles could allow them to be used in information-storage devices. “We could store information in the internal states of paraparticles, and information stored this way should be robust against noise,” he says. Such a use, however, is likely not on the immediate or even intermediate horizon, says Paul Fendley, who studies the collective behavior of many-particles systems at the University of Oxford. The prediction of paraparticles relies on the fine-tuning of particle properties in the model developed by Wang and colleagues, Fendley says. “It’s unlikely you could realize this particle in this predicted form.” Even with that large caveat, Fendley says that the finding still has merit. “These particles are kind of cool.”

Katherine Wright is the Deputy Editor of ***Physics Magazine***.

## REFERENCES

1. Z. Wang and K. R. A. Hazzard, “Particle exchange statistics beyond fermions and bosons,” **Nature 637, 314 (2025).**