Quantum Entanglement Could Stretch Across Time

By Lisa Grossman January 21, 2011

In the weird world of quantum physics, two linked particles can share a single fate, even when they're miles apart.

Now, two physicists have mathematically described how this spooky effect, called entanglement, could also bind particles across time.

If their proposal can be tested, it could help process information in quantum computers and test physicists' basic understanding of the universe.

"You can send your quantum state into the future without traversing the middle time," said quantum physicist S. Jay Olson of Australia's University of Queensland, lead author of the new study.

In ordinary entanglement, two particles (usually electrons or photons) are so intimately bound that they share one quantum state — spin, momentum and a host of other variables — between them. One particle always "knows" what the other is doing. Make a measurement on one member of an entangled pair, and the other changes immediately.

Physicists have figured out how to use entanglement to encrypt messages in uncrackable codes and build ultrafast computers. Entanglement can also help transmit encyclopedias' worth of information from one place to another using only a few atoms, a protocol called quantum teleportation.

In a new paper posted on the physics preprint website arXiv.org, Olson and Queensland colleague Timothy Ralph perform the math to show how these same tricks can send quantum messages not only from place to place, but from the past to the future.

The equations involved defy simple mathematical explanation, but are intuitive: If it's impossible to describe one particle without including the other, this logically extends to time as well as space.

"If you use our timelike entanglement, you find that [a quantum message] moves in time, while skipping over the intermediate points," Olson said. "There really is no difference mathematically. Whatever you can do with ordinary entanglement, you should be able to do with timelike entanglement."

Olson explained them with a *Star Trek* analogy. In one episode, "beam me up" teleportation expert Scotty is stranded on a distant planet with limited air supply. To survive, Scotty freezes himself in the transporter, awaiting rescue. When the *Enterprise* arrives decades later, Scotty steps out of the machine without having aged a day.

"It's not time travel as you would ordinarily think of it, where it's like, *poof!* You're in the future," Olson said. "But you get to skip the intervening time."

According to quantum physicist Ivette Fuentes of the University of Nottingham, who saw Olson and Ralph present the work at a conference, it's "one of the most interesting results" published in the last year.

"It stimulated our imaginations," said Fuentes. "We know entanglement is a resource and we can do very interesting things with it, like quantum teleportation and quantum cryptography. We might be able to exploit this new entanglement to do interesting things."

One such interesting thing could involve storing information in black holes, said physicist Jorma Louko, also of the University of Nottingham.

“They show that you can use the vacuum, that no-particle state, to store a lot of information in just a couple of atoms, and recover that info from other atoms later on,” Louko said. “The details of that have not been worked out, but I can foresee that the ideas that these authors use could be adapted to the black hole context.”

Entanglement in time could also be used to investigate as-yet-untested fundamentals of particle physics. In the 1970s, physicist Bill Unruh predicted that, if a spaceship accelerates through the empty space of a vacuum, particles should appear to pop out of the void. Particles carry energy, so they would be, in effect, a warm bath. Wave a thermometer outside, and it would record a positive temperature.

Called the Unruh effect, this is a solid prediction of quantum field theory. It’s never been observed, however, as a spaceship would have to accelerate at as-yet-unrealistic speeds to generate an effect large enough to be testable. But because timelike entanglement also involves particles emerging from vacuums, it could be used to conduct more convenient searches, relying on time rather than space.

Finding the Unruh effect would provide support for quantum field theory. But it might be even more exciting not to see the effect, Olson said.

“It would be more of a shocking result,” Olson said. “If you didn’t see it, something would be very wrong with our understanding.”