Fighting the Quantum Conspiracy

Recently scientists described what they called a “quantum trick which can be played to fight the quantum conspiracy.” To understand what they mean, they start by revisiting a famous finding in quantum physics, **Heisenberg’s uncertainty principle**. Named for the early-twentieth century German physicist Werner Heisenberg, this principle states that we cannot know either the position or the momentum of any particle exactly. Furthermore, our uncertainty about each quantity is dependent on our uncertainty in the other. If we have very precise knowledge of one quantity, the other must be highly uncertain.

What a pain for scientists! That means if we work really hard to measure the position of a particle exactly, the laws of quantum physics seemingly conspire against us to make it impossible to know the momentum of that particle.

To visualize the issue, look at **Figure 1a,** which shows a particle which starts near the origin of the *x*- and *y*-axes. The shaded, fuzzy area around the origin represents our uncertainty in the position. This hypothetical particle also has some momentum, so over time it will move and have a new position. As time increases, the figure shows two things. First, you can see the particle moving along some trajectory. Second, you can see the size of the fuzzy area increase. The reason is that the momentum is uncertain: since we cannot know the velocity vector (the direction and rate of motion) of the particle, our uncertainty in its position will grow more and more uncertain over time until we measure its position again.

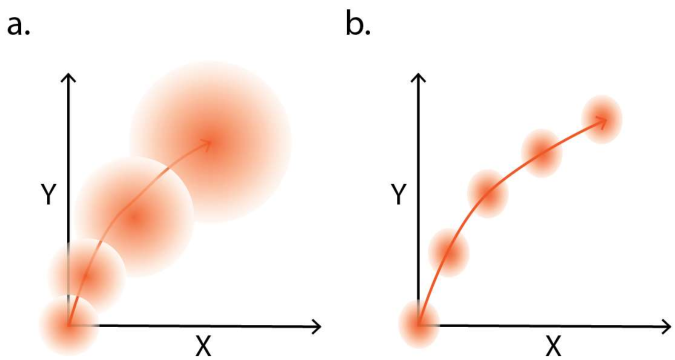

Figure 1. Particle Trajectory. The trajectory of a particle as measured (a) normally and (b) by comparing its motion to a particle with negative mass. Notice that by measuring the position of the particle in relation to its position to a particle with negative mass, there is less uncertainty regarding its position over time.

To address this issue, scientists at the Leibniz University Hannover in Germany and Copenhagen University in Denmark built on recent experiments that seem to suggest the possibility of particles that have negative mass. Of course, in classical physics it is not possible for mass to be negative. But quantum mechanics is...special. Some quantum theories require that, just as positive electrical charges have negative counterparts, regular, everyday positive masses have negative counterparts. Very few experiments or observations have ever shown anything that seems to be a particle with negative mass, although science fiction authors have explored wondrous consequences of such a possibility. For instance, some theories that rely on negative mass allow for the existence of wormholes linking distant locations in the universe.

Although they don’t explore the possibility of wormholes, the researchers behind this study do show that it’s possible to know the trajectory (path) of a particle in spite of the uncertainty principle. The trick is to measure the particle’s position (to choose the origin of the coordinate system) relative to another, special quantum particle—one with negative mass. Look at

Figure 1b. When measured relative to a negative-mass particle, the uncertainty in position (the size of the fuzzy area) does not grow over time!

This is all theoretical of course, but the modeling shows promise.The author's argue that someday this technique could be used to measure force and acceleration with unprecedented precision. It's important to remember that the questions posed by these researchers relate to the interactions of particles far too small for the eye to see; they do not describe any phenomenon we will experience directly as human beings. However, the work of these scientists has profound implications for how we understand the fundamental operation of our universe.

Reference

Polzik, Eugene S., and Klemens Hammerer. "Trajectories without Quantum Uncertainties." *Annalen Der Physik* 527, no. 1-2 (2014). doi:10.1002/andp.201400099.

BiteScientist Profiles

Nathan Sanders is an astrophysicist and statistician working in industry. His astronomical research focused on core-collapse supernovae, the explosive deaths of the most massive stars in the universe. Like the science in this bite, those explosions rely on laws of physics at scales unlike anything we experience day to day on Earth. Nathan's statistical work focuses on helping entertainment companies understand, predict, and serve consumer's interests and preferences for film, TV, and other content. In his free time, Nathan enjoys hiking, gardening, and playing video games.

Shannon Morey is a physics and chemistry teacher at Abbott Lawrence Academy, a public exam high school in Lawrence, MA. She previously worked as a physics and chemistry teacher at East Boston High School and is a member of the leadership team for ComSciCon, a national workshop for graduate students interested in science communication. Shannon also enjoys traveling, hiking, cooking, and hanging out with her two cats.