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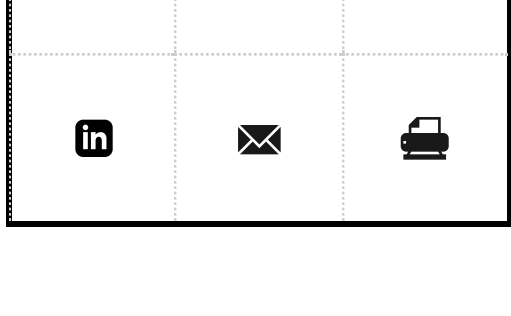


QUANTUM PHYSICS

6 Times Quantum Physics Blew Our Minds in 2022

Quantum telepathy, laser-based time crystals, a glow from empty space and an “unreal” universe—these are the most awesome (and awfully hard to understand) results from the subatomic realm we encountered in 2022

By Lee Billings on December 19, 2022



Credit: sakkmeisterke/ Getty Images

The quantum world defies common sense at every turn. Shaped across hundreds of thousands of years by biological evolution, our modern human brain struggles to comprehend things outside our familiar naturalistic context. Understanding a predator chasing prey across a grassy plain is easy; understanding most anything occurring at subatomic scales may require years of intense scholarship and oodles of gnarly math. It's no surprise, then, that every year physicists deliver mind-boggling new ideas and discoveries harvested from reality's deep underpinnings, well beyond the frontiers of our perception. Here, *Scientific American* highlights some of our favorites from 2022.

THE UNIVERSE IS KINDA, SORTA UNREAL

This year's [Nobel Prize in Physics](#) went to researchers who spent decades [proving the universe is not locally real](#)—a feat that, to quote humorist Douglas Adams, “has made a lot of people very angry and been widely regarded as a bad move.” “Local” here means any object—an apple, for instance—can be influenced only by its immediate surroundings, not by happenings on the other side of the universe. “Real” means every object has definite properties regardless of how it is observed—no amount of squinting will change an apple from red to green. Except careful, repeated experimentation with entangled particles has conclusively shown such seemingly sensible restrictions do not always apply to the quantum realm, the most fundamental level of reality we can measure. If you're uncertain as to what exactly the demise of local realism means for life, the universe and, well, *everything*, don't worry: you're not alone—[physicists are](#) befuddled, too.

LASERS CREATE TIME CRYSTALS AND PORTALS TO HIGHER DIMENSIONS

Despite seeming like plot elements of a [cult-classic science-fiction film](#), two unrelated papers published earlier this year describe not-at-all-fictitious ways of harnessing light at the quantum frontier. In one study, researchers reported [the first-ever construction of laser-based time crystals](#), quantum systems that exhibit crystallike periodic structures not in space but in time. In the other, a team detailed how precise patterns of laser pulses coaxed strings of ions into behaving like a [never-before-seen phase of matter occupying two time dimensions](#). The former study could lead to cheap, rugged microchips for making time crystals outside of laboratories. The latter suggests a method for enhancing the performance of quantum computers. For most of us, though, these studies may be most useful for sounding smart at cocktail parties.

QUANTUM TELEPATHY CONQUERS AN UNBEATABLE GAME

The Mermin-Peres magic square (MPMS) game is the sort of competition one can win only by not playing. This dismal relative of Sudoku involves two participants taking turns adding the value of either +1 or −1 to cells in a three-by-three grid to collaboratively fulfill a win condition. Although the players must coordinate their actions to succeed, they are not allowed to communicate. And even if each correctly guesses the other's move, the pair can still only win eight out of the game's nine rounds—unless, that is, they play a quantum version. If qubits (which can swap values between +1 and −1) are used to fill each cell, two players can, in theory, pull off a perfect run by avoiding conflicting moves for all nine rounds. In practice, however, the odds of guessing each move correctly are vanishingly slim. Yet by carefully leveraging entanglement between the qubits, during each turn, the players can surmise each other's actions without actually communicating—a vexing technique known as [quantum pseudotelepathy](#). In July researchers published a paper reporting their [successful real-world demonstration](#) of this strategy to achieve flawless performance.

This isn't all fun and games, either: such work probes the fundamental limits of how information can be shared between entangled particles.

TESTING THE UNTESTABLE UNRUH EFFECT

According to the tenets of quantum field theory—an uneasy union between Einstein's special theory of relativity and quantum mechanics used to model the behavior of subatomic particles—empty space isn't actually empty. Instead what we perceive as the void is filled with overlapping energetic fields. Fluctuations in these fields can produce photons, electrons and other particles essentially out of “nothing.” Among the various bizarre phenomena predicted to arise from such curious circumstances, the strangest might be the [Unruh effect](#), a warm shroud of ghostly particles summoned by any object accelerating through a vacuum. Named for theorist Bill Unruh, who described it in 1976, this effect is so subtle that it has yet to be observed. That soon could change if a [tabletop experiment proposed in April](#) is successfully performed. The experiment involves accelerating a single electron through an intense and carefully configured electromagnetic field. This setup should lower the threshold of acceleration for the Unruh effect to visibly manifest, boosting the chances for catching a glimpse of its elusive quantum glow, the proposers say.

A NEW ANGLE ON QUANTUM SPIN

Not all counterintuitive quirks of quantum physics are linked to natural causes. Some are arguably more self-inflicted, arising from researchers' questionable choices in how they name and describe certain phenomena. Consider the case of quantum “spin,” the label affixed to the angular momentum that is intrinsic to elementary particles. The term is confusing because such particles *cannot* physically spin—if they were simply ever twirling subatomic gyroscopes, their rotation would be impossibly fast, well in excess of the speed of light. But [quantum spin is crucial](#) to accounting for the observed behavior of electrons and other particles: although they may not actually be physically spinning, the particles are clearly doing *something*. Exactly what that “something” is can be captured with utmost accuracy by mathematical equations, but its causal physical basis remains murky. One relatively new (and highly controversial) hypothesis appeals to quantum field theory for an explanation. In this proposal, particles (which arise from fluctuations in quantum fields) gain their spin (angular momentum) from their originating fields, somewhat like a turbine being spun by the wind. “If this is where the angular momentum resides,” *Scientific American's* [article on the idea](#) noted, “the problem of an electron spinning faster than the speed of light vanishes; the region of the field carrying an electron's spin is far larger than the purportedly pointlike electron itself.”

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