

# SPOOKY ACTION AT A DISTANCE



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## HOW WE THINK OF SPACE

If there is space between two objects—if there are two birds in the sky and one is way off to your right and the other is way off to your left—we can and do consider the two objects to be independent. We regard them as separate and distinct entities. Space, whatever it is fundamentally, provides the medium that separates and distinguishes one object from another. That is what space does. Things occupying different locations in space are different things.

Moreover, in order for one object to influence another, it must in some way negotiate the space that separates them. One bird can fly to the other, traversing the space between them, and then peck or nudge its companion. One person can influence another by shooting a slingshot, causing a pebble to traverse the space between them, or by yelling, causing a domino effect of bouncing air molecules, one jostling the next until some bang into the recipient's eardrum.

Being yet more sophisticated, one can exert influence on another by firing a laser, causing an electromagnetic wave—a beam of light—to traverse the intervening space. Or, being more ambitious, one can hypothetically shake or move a massive body (like the moon), sending a gravitational disturbance speeding from one location to another.

To be sure, if we are over here, we can influence someone over there; but no matter how we do it, the procedure always involves someone or something traveling from here to there, and only when the someone or something gets there can the influence be exerted.

## VOODOO REALITY

Physicists call this feature of the universe *locality*, emphasizing the point that you can directly affect only things that are next to you, that are local. Voodoo contravenes locality, since it involves doing something over here and affecting something over there without the need for anything to travel from here to there, but common experience leads us to think that verifiable, repeatable experiments would confirm locality. And most do.

But a class of experiments performed during the last couple of decades has shown that something we do over here (such as measuring certain properties of a particle) *can* be subtly entwined with something that happens over there (such as the outcome of measuring certain properties of another distant particle), *without* anything being sent from here to there.

***Intervening space does not ensure that two objects are separate.***

While intuitively baffling, this phenomenon fully conforms to the laws of quantum mechanics, and was predicted using quantum mechanics long before the technology existed to do the experiment and observe, remarkably, that the prediction is correct. This sounds like voodoo; Einstein, who was among the first physicists to recognize—and sharply criticize—this possible feature of quantum mechanics, called it "spooky."

***Quantum connections between two particles can persist even if the two particles are on opposite sides of the universe.***

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Nevertheless, these results, coming from both theoretical and experimental considerations, strongly support the conclusion that the universe admits interconnections that are not local. Something that happens over here can be entwined with something that happens over there even if nothing travels from here to there—and even if there isn't enough time for anything, even light, to travel between the events.

This means that space cannot be thought of as it once was: Intervening space, *regardless of how much there is*, does not ensure that two objects are separate, since quantum mechanics allows an entanglement, a kind of connection, to exist between them.

According to quantum theory and the many experiments that bear out its predictions, the quantum connection between two particles can persist *even if they are on opposite sides of the universe*. From the standpoint of their entanglement, notwithstanding the many trillions of miles of space between them, it's as if they are right on top of each other.

Numerous assaults on our conception of reality are emerging from modern physics. But of those that have been experimentally verified, I find none more mind-boggling than this recent realization that our universe is not local.