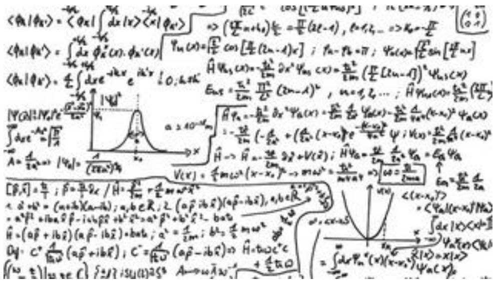
THE HINDU

## Blogs » The Copernican

Published: February 24, 2014 19:56 IST | Updated: February 24, 2014 21:35 IST

# For the last loophole, let there be light!

Vasudevan Mukunth



If you don't understand this, don't fret. Physicists don't get it fully either. *ShutterStock*

Vasudevan Mukunth
Vasudevan Mukunth writes on science and technology for The Hindu, and manages The Hindu Blogs. »
E-mail: vasudevan.m@thehindu.co.in

***In 1964, a physicist came up with an experiment to settle a three-decade old debate centered on one question: is quantum mechanics a valid theory of the world? If an announcement from MIT is anything to go by, we may finally have one of the last pieces of this puzzle.***

A coherent understanding of the universe has eluded humankind for ever. On the one hand, Albert Einstein's theories help us understand the behaviour of larger things, such as everyday objects, planets, stars and galaxies. On the other, a set of rules called quantum mechanics describe the behaviours of the smaller things, like atoms and subatomic particles. Unfortunately, Einstein's theories and quantum mechanics have not been able to explain the same thing.

If they did, then we would finally have what physicists call a unified theory of reality—one theory to rule them all!

These days, one of the biggest problems in physics is to unite the two theories smoothly. However, there was a time when physicists fought about whether the other theory was even right. In 1935, Albert Einstein, Boris Podolsky and Nathan Rosen were three such, known together as EPR. They argued that there was a problem with a part of quantum mechanics called the Heisenberg's uncertainty principle.

The principle states that a particle's position and momentum can't be known at the same time. This means whenever we measure an electron's position, we won't know its speed. When we measure its speed, we won't know its position.

### A cracked edifice?

Instead of measuring the position and momentum of one particle, EPR suggested measuring two particles that had interacted briefly before moving off in opposite directions. Let's call them A and B.

According to Heisenberg, it is impossible to measure the position and momentum of A at the same time. However, EPR calculated that because the two particles had interacted, measuring A's properties will tell us about B's properties without B having to be physically measured. According to the trio, this implied that the particles contained some information—in the form of *hidden variables*—that determined the outcomes of all future measurements on them.

This flew in the face of Heisenberg's principle. Here was a valid argument levelled against one of the most prominent edifices of quantum mechanics. How was it to be countered?

It was, almost 30 years later by an Irish physicist named John Bell. It had been known that Einstein, Podolsky and Rosen had made two assumptions in their argument: reality and locality. Bell was able to find that one of the two assumptions had to be false, a conclusion called Bell's inequality. Following this was Bell's theorem: *No physical theory of local hidden variables can ever reproduce all of the predictions of quantum mechanics*.

Bell calculated that particles could be prepared in such a way that they behaved the way they did in the EPR paradox. Bell was also able to show that quantum mechanics could explain their behaviour by describing an experiment which would show that the particles couldn't contain any information in the form of hidden variables.

"What John Bell quantified in his elegant 1964 article was that any rival theory that depends on a certain class of these hidden variables necessarily makes different empirical predictions for experiments than do the equations of quantum mechanics," Prof. Kaiser summarised.

### Poking holes in the experiment

Experiments performed to test Bell's theorem have consistently favoured quantum mechanics over a physical theory with hidden variables in the last 50 years. However, they haven't been decisive because they have been beset by three nagging flaws arising from the experiment's design. They are:

1. **No-signalling** Whether anything about the events at one detector could have been transmitted to the second detector. This was one of the first loopholes to be closed, by performing experiments far enough from each other as simultaneously as possible.

2. **Fair-sampling** No detector is perfect and can't measure all particles headed its way. So it becomes possible that they could be measuring a biased sample of particles. This loophole has also been closed—by using lots of particles and a large number of detectors such that, on average, fair samples are measured.

3. **Free-will** Whether the choices of what properties to measure with the detectors could have been affected in any way by any event or hidden information in the detectors' pasts.

If all these flaws aren't removed, then, as Prof. Kaiser remarked, "there remains the logical possibility that quantum mechanics is actually incorrect, and the experimental results arose because of a failure of one of Bell's underlying assumptions." In other words, the experiment will seem as if it favours quantum mechanics but will actually be adherent to classical laws of physics.

So, on February 20, Prof. Kaiser, post-doctoral student Andrew Friedman, also at MIT, and Jason Gallicchio of the University of Chicago came up with a new way to plug the third loophole. For help, they have "decided to use the entire history of the universe."

### Ancient light

Quasars are some of the oldest objects in the universe: some of them are many billions of years old. They are known by the very bright light that they emit—so bright that they rival those of stars. In fact, that's where they get their name from: **quas**i-stell**ar**.

A quasar is the region of space surrounding the centres of giant galaxies, around supermassive black-holes if there are any. As matter from the galaxy is swallowed by the black-hole, it emits radiation. As more matter falls in, the brighter the radiation, and where it all seems to come from is called the quasar.

By carefully selecting two quasars, Prof. Kaiser and his team want to have access to two sources of light that have never had a chance to interact since the beginning of the universe. By extension, their light will have never had the chance to interact, precluding any entangle or cosmic conspiracy between them. By further extension, one quasar's past will have had nothing to do with the other quasar's past.

According to the free-will loophole, the same can't be said of the detectors. What if the detector's settings are biased in the sense that the person using it can only choose some settings because the others are just forbidden because of the science behind it? As far-fetched as it sounds, this loophole is still logical and has to be plugged before the experiment can be ideal.

And to do so, Prof. Kaiser and co. propose that they use light from the quasars to tell them which properties of the particles each detector will measure. That is, some properties of the light from quasar A will determine which properties of particle A are measured by detector A. Some properties of the light from quasar B will determine which properties of particle B are measured by detector B.

Because the quasars have not had a chance to meet each other, their light will give physicists and their experiments a semblance of free will: "There should not be any way in which the choices of how to set the detectors could have been biased or affected by some third party or some event in their shared past," assured Prof. Kaiser.

### Now, all three at once

He also told me that he and his colleagues were able to elicit interest from Anton Zeilinger, a famous Viennese quantum physicist. The Zeilinger Group, as his team is known, has been performing Bell's theorem experiments, in a bid to confirm that quantum mechanics is a valid theory, at the Vienna Centre for Quantum Science and Technology. If they perform an experiment to close the free-will loophole, then scientists will once and for all know ways to close all three loopholes.

That won't be the end of the story, however, because there will be one final problem. To date, no Bell's theorem experiment has been able to close all three loopholes at once. "If that experiment were conducted, and the predictions of quantum mechanics were still borne out, then for the first time we could say with utmost confidence that we have ruled out, as far as possible, any rival hypothesis or alternative to quantum mechanics, at least of the sort that Bell had been concerned with," Prof. Kaiser says.

And with that, physicists would have the best reason ever to be confident about the strange yet beautiful theory of quantum mechanics.

Keywords: quantum mechanics, classical physics, EPR paradox, Albert Einstein, John Bell, Bell's theorem, logic, quasars

Posts on science, its history and philosophy, and why these things matter. Named for the 16th century Polish astronomer who dislodged Earth from the centre of the universe.

THE COPERNICAN

Printable version | Feb 26, 2014 12:11:44 PM | http://www.thehindu.com/opinion/blogs/blogs-the-copernican/article5722821.ece