Despairing Still?

Are there reasons to believe that standard quantum mechanics is insufficient?

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by MIKE PERRICONE

Conference Idea: Is quantum mechanics insufficient? March 7, 2008

Max Planck regarded quantum theory as "an act of despair" – and he's the one who started the whole thing.

Ever since Planck discovered that energy is transmitted in discrete packets more than one hundred years ago, scientists have been grappling with the consequences of the quantum theory that resulted.

Probability, the uncertainty principle, wave-particle duality – even the esteemed Niels Bohr and Werner Heisenberg, inventors of the 'Copenhagen interpretation' of quantum mechanics, had problems working with Planck's model for the behavior of energy and matter at the subatomic level.

STEVEN GRATTON
Cambridge University

Still, physicists today know that the theory works, since it correctly predicts any number of microscopic phenomena, though the how and why remain puzzling. Perhaps the theory, while correct in the main, is lacking in some particular?

"I feel that quantum mechanics is sometimes counterintuitive but not necessarily insufficient," says Steven Gratton of Cambridge University. "What is more likely to be insufficient is our understanding of our perception of quantum mechanical systems, the emergence of probabilities, and the semiclassical limit, which is a useful classical picture for approximating a quantum system. "

John Donoghue of the University of Massachusetts concurs: "Physics is an experimental science and there is really no experimental indication of any deficiency with standard quantum mechanics. This is a major point. There are all sorts of experimental hints for deficiencies with our present theories, but they all point in different directions other than flaws in quantum mechanics."

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>
> *- John Donoghue*

Sufficient or no, the fact remains that quantum mechanics cannot be currently rectified with the other major achievement of twentieth century physics: general relativity, which describes large objects, such as planets, galaxies, and the Universe. So a "big picture" – a quantum view of the Universe – remains a big puzzle.

Planck despairs still.

MIA: Quantum Gravity

"We need to find a theory of Quantum Gravity," says Lucien Hardy of Canada's Perimeter Institute, speaking for many physicists. "This means finding a theory which has standard quantum theory and general relativity as appropriate limiting cases," Hardy says.

This is easier said than done. "It is very hard to know how to apply quantum mechanics to the Universe as a whole," Donoghue says. "The standard interpretation [of quantum theory] involves a system and an observer. This does not work for the Universe as a whole," since we are unable to test quantum mechanics on a universal scale.

Hardy sees other difficulties. He says that most people working on quantum gravity – for example, string and loop quantum gravity theorists – attempt to formulate the theory using a standard quantum theory framework. "I believe this is not going to work," Hardy says,

JOHN DONOGHUE
University of Massachusetts

"because general relativity is radical in ways that quantum theory is not. Rather, I think we need a new framework, which can admit the radical features of quantum theory and general relativity. This will force us out of the standard quantum theory framework."

In his search for a new framework, Hardy thinks the measurement problem – or as physicist Philip Pearle termed it, "the reality problem" – is a top priority.

In quantum mechanics, the superposition principle suggests that an unobserved object can exist in many possible (quantum) states at the same time. But when we try to make a measurement, reality intrudes: we limit the object to a single state. Hence the measurement/reality problem: "Why do we see definite outcomes," asks Hardy, "whereas standard unitary quantum theory predicts a superposition of outcomes for measurements?"

LUCIEN HARDY
Perimeter Institute

Ken Olum of Tufts University seems to agree. "[I]t would be nice to settle the question of what one would observe if one lived inside the simple scenario of quantum mechanics, without considerations such as extra wave-function-collapse postulates."

Hardy suggests physicists might solve the reality problem by changing quantum mechanics' equations to show explicit wave function collapse in large-scale systems. Other approaches, such as one by Antony Valentini at Imperial College, involve supplementing standard quantum theory with hidden variables, which would determine the outcome that actually occurs.

In a third view, Robert Spekkens of Cambridge University believes the "reality problem" might stem from an observer's limited knowledge of the entirety of states available in a physical system. "The only statement of [quan

KEN OLUM
Tufts University

tum] theory that is uncontroversial," Spekkens says, "is one that simply specifies the relative frequencies of outcomes [that] will be observed when a given measurement follows a given preparation, for instance, the probability that a detector will make an audible 'click'. But the very existence of detectors that click is the sort of thing that we can and should look to science to explain."

Spekkens searches for a version of quantum theory that will allow a complete scientific worldview, incorporating not just laboratory physics, but all scientific disciplines, from evolutionary biology to cosmology.

Did anyone say "Theory of Everything"?

Minor Details

Of course, quantum mechanics could someday be shown to be in error by an unexpected result.

"Quantum mechanics can certainly be falsified," Donoghue says. "It makes many

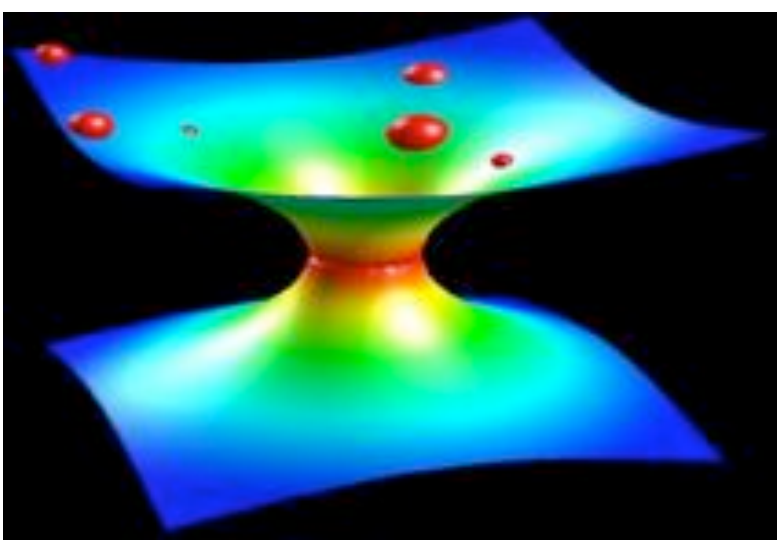
ROBERT SPEKKENS
Cambridge University

predictions, such that some may be wrong. It is certainly worthwhile to test quantum theory experimentally in novel and extreme conditions."

But, today, quantum theory continues to rule.

"Quantum theory provides a framework for physical theories," says Hardy. "The real question is whether we will reach a point where a quantum explanation looks unnatural. I think this will happen in quantum gravity, but it remains to be seen."

Sounds like Max Planck may despair for some time to come.



QUANTUM GRAVITY A model of a "big bounce" (red band), from which particles emerge (red dots) in quantum gravity. Time runs bottom to top in this image; space contracts then expands. Image Credit: Cliff Pickover, pickover.com