and he is correct in rejecting the notion of the quantum state "collapsing" after a measurement.

QBism begins with the assumption that all kinds of probability can be regarded as subjective Bayesian probabilities. That assumption can be maintained only by ignoring the literature on interpretations of probability, from which it is clear that several different kinds—or interpretations—of probability exist. DiVincenzo and Fuchs may have ignored the classic philosophical writings on the subject because they were written by philosophers for philosophers and so do not address the needs of physicists.

I have published a paper on the foundations of probability theory, written from the point of view of a quantum physicist.[3] I classify the main kinds or interpretations of probability into three groups: inferential probability, of which Bayesian theory is an example; frequency or ensemble probability, commonly used in Gibbsian statistical mechanics and in QM; and propensity theory. Propensity, a degree of causality that is weaker than determinism, is not merely another interpretation of probability. Its mathematical theory must also differ from that of probability theory, as Paul Humphreys showed[4] in 1985. Although the axioms of propensity[3] differ from those of probability, the two axiom sets overlap. Both support the law of large numbers, so propensity theory is compatible with the most useful part of the frequency interpretation of probability.

In general, QM states do not determine the results of a measurement, only the probabilities of the possible results. That a state's influence on the results is not deterministic suggests strongly that the quantum probabilities given by the Born rule should be interpreted as propensities. They refer objectively to the physical system and its environment, not to any agent's knowledge, so they are not naturally interpreted as subjective Bayesian probabilities.

Interpretations of probability may differ not only in philosophy but also in substance. As I discuss in reference 3, John Bell's theorem illustrates how local hidden-variable theories are incompatible with QM. E. T. Jaynes was a well-known supporter of the Bayesian theory of probability. In 1989 he repeated Bell's derivation of inequality but carefully treated all instances of probability as Bayesian. He found that the derivation could not be completed without invoking an extra assumption that was not justifiable in the Bayesian theory. Bell's theorem involves questions about causality, so it is natural to use propensity theory to treat it. That method is successful in deriving Bell's inequality.[3]

Not all probabilities occurring in QM can be treated as subjective Bayesian probabilities. That limitation disqualifies QBism, a Bayesian-based theory, as an interpretation of QM that can succeed in quantum foundations. The initial assumption of QBism is not valid.

References

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▶ **DiVincenzo and Fuchs reply:** We deeply regret our oversight of Leslie Ballentine's influential 1970 *Reviews of Modern Physics* article on the ensemble interpretation. We were well aware of the paper but had not realized that it appeared in *RMP* so as to be appropriate for the retrospective. We apologize to Ballentine and to our readership.

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Celestial background of 1869 eclipse

I enjoyed Deborah Kent's article on American efforts to document and study the 1869 total solar eclipse (Physics Today, August 2019, page 46). At the April 2019 meeting of the American Physical Society, we were treated to a session titled "Centennial of the Eddington Eclipse Expedition."

I'm curious. Were stars visible in any of the photos of the 1869 eclipse—or other eclipses in the days before general relativity? And would it have been possible that someone noticed the displacement of the stars' positions as Arthur Eddington did in 1919, but before Albert Einstein published his theory in 1915?

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▶ **Kent replies:** I'm glad Robert McAdory enjoyed the article. Although I'm not aware of any photos from the 1869 eclipse that show visible stars, there were images on plates from eclipses before 1919. Expeditions from the Lick, Yerkes, Smithsonian Astrophysical, and US Naval Observatories took large-format images of the corona during the 28 May 1900 eclipse, when the star field was similar to that during the 29 May 1919 eclipse. The images taken by Lick and their possible connections to the relativity test are explored in chapter five of Jeffrey Crelinsten's *Einstein's Jury: The Race to Test Relativity* (2006) and chapter two of *No Shadow of a Doubt: The 1919 Eclipse That Confirmed Einstein's Theory of Relativity* (2019) by Daniel Kennefick.

The 19th-century searches for an intramercurial planet resulted in many images in which some background stars might be visible. The *Lick Observatory Bulletin*, number 24 (1902), reported that half of the observatory's plates from the eclipse of 18 May 1901 included star images. That report also has more specific information about Lick's capabilities to capture stars in images.

My thanks to Tom English of the Cline Observatory, Jamestown, North Carolina.

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