

tion of quantum theory without hidden variables removes any worry about a conflict with special relativity.

Although Bohmian mechanics was worthy of consideration and has been useful in the development of quantum foundations, ignoring more recent developments is not the way to honor the memory of one of the great physicists of the last century. I hope that a second edition of Norsen's well-written book will take account of more recent work.

References

1. J. S. Bell, *Speakable and Unspeakable in Quantum Mechanics: Collected Papers on Quantum Philosophy*, Cambridge U. Press (1987).
2. R. B. Griffiths, *Phys. Lett. A* **261**, 227 (1999).
3. See R. B. Griffiths, *Found. Phys.* **41**, 705 (2011), and references therein.
4. J. von Neumann, *Mathematical Foundations of Quantum Mechanics*, R. T. Beyer, trans., Princeton U. Press (1955), chap. 3.5.

Robert B. Griffiths

(rgrif@cmu.edu)

Carnegie Mellon University
Pittsburgh, Pennsylvania

► **Bricmont replies:** I find it odd, as the reviewer of a book, to be criticized because I did not discuss a theory that was not mentioned in the book. But I'll answer Robert Griffiths point by point.

In Bohmian mechanics (BM), it is simply a mathematical fact, noted by John Bell in chapter 14 of reference 1 of the Griffiths letter, that in the delayed double-slit experiment Griffith describes, particles cannot cross a symmetry plane but instead bounce back from it.¹ Offering a different theory in which particles follow a different trajectory does not refute that fact.

In standard quantum mechanics (QM), particles do not have trajectories; that fact was emphasized by, among others, Richard Feynman² and Lev Landau and Evgeny Lifshitz.³

The theory by Griffiths, based on the idea of "consistent histories," is therefore not standard QM but is instead, like BM, an attempt to complete QM, by adding histories that consist of real events that occur independently of any measurements made on the quantum system (a measurement means an interaction with that system that may affect what would happen to it in the absence of measurements). Unfortunately, Griffiths's attempt runs into contradictions, as shown in particular by Sheldon Gold-

stein in his two-part feature for *PHYSICS TODAY* (March 1998, page 42, and April 1998, page 38).

Griffiths misses the first step in Bell's proof of nonlocality: the Einstein-Podolsky-Rosen (EPR) dilemma that perfect correlations between distant events cannot be explained unless one supposes either that some form of action at a distance occurs or that the events are predetermined by antecedent causes. The latter assumption is *not* a "classical" one; it is one part of the EPR dilemma. But Bell showed with his inequalities that the assumption leads to a contradiction. Hence, nonlocality follows. For more details, see, for example, references 1 and 4 and Travis Norsen's book.

References

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2. R. Feynman, *The Character of Physical Law*, MIT Press (1967), p. 145.
3. L. D. Landau, E. M. Lifshitz, *Quantum Mechanics: Non-Relativistic Theory*, 2nd ed., J. B. Sykes, J. S. Bell, trans., Pergamon Press (1965), p. 2.
4. R. Tumulka, "The assumptions of Bell's proof," *International Journal of Quantum Foundations* (21 December 2014).

Jean Bricmont

(jean.bricmont@uclouvain.be)

Research Institute in
Mathematics and Physics
University of Louvain
Louvain-la-Neuve, Belgium

Temperature inversions in theory and in Pittsburgh

I recently read Tony Sadar's Quick Study, "Waking up to temperature inversions" (*PHYSICS TODAY*, October 2018, page 74). I write to clarify a couple of points that could be misunderstood, and I have an important and interesting addition about the way that inversions form around Pittsburgh, Pennsylvania.

The Quick Study's figure 1 could be read as indicating that sunlight intensity increases linearly from zero at 6 am to a maximum at solar noon and then decreases linearly to zero at 6 pm. In fact, sunlight intensity is not linear through

the day; it follows a sine function from sunrise to sunset.

Similarly, the plot should not be understood as saying that temperature rises and falls linearly. To a first approximation, air temperature near Earth's surface follows a sine curve from a minimum temperature near sunrise to a maximum temperature two hours after solar noon and declines along the sine curve until sunset. After sunset, air temperature falls exponentially to a minimum near sunrise.

I would also like to mention an important part of inversion formation in complex terrain. A hilltop cools much faster than the valley floor, and as a result, cooler, denser air flows downhill and into the valley. Cooler air pooling in the valley undercuts warmer air and creates an inversion, as shown in panel c in the Quick Study's figure 2. As Sadar notes, Pittsburgh is surrounded by hilly environs.

Dale Edward Linvill

(dlinvill@nctv.com)

Clemson University
Clemson, South Carolina

► **Sadar replies:** I appreciate Dale Linvill's thoughtful comments. His mention of the downward flow of cold air that can form substantial ground-level temperature inversions in valleys is a good example of inversion formation in complex terrain.

As for his critique of the diurnal-temperature and sunlight-intensity graphs, his description provides helpful details of thermal and solar-impact changes throughout a 24-hour period. However, the graphs were stylized and simplified to convey the general nature of conditions that affect the formation of surface-temperature inversions. In addition, the temperature graph roughly mimics actual measurements observed in the Pittsburgh area.

Tony Sadar

(anthony.sadar@alleghenycounty.us)

Allegheny County Health Department
Pittsburgh, Pennsylvania

Correction

August 2019, page 66—In figure 1, the eclipse path labeled 2021 June 10 should read 2021 December 4. A corrected map can be found online. —Jay Pasachoff 