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Paper Title: **My two fateful encounters with Berge (so far)**

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Personal message:

My two fateful encounters with Berge (so far)

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My first published paper[1], which appeared in *American Journal of Physics* in 1996, was titled "Restoration of interference and the fallacy of delayed choice: Concerning an experiment proposed by Englert, Scully and Walther." Not long after its publication, while I was thinking about a response to David Mermin's article "What is quantum mechanics trying to tell us?"[2], which became my article "What quantum mechanics is trying to tell us"[3], I realized that I had made a mistake. I hadn't heeded Nico van Kampen's warning that "whoever endows the wave function with more meaning than is needed for computing observable phenomena is responsible for the consequences"[4].

In this case the first consequence was that I was asked by the then Editor of *American Journal of Physics* to review an article by Englert, Scully, and Walther that was intended "to set the record straight." Subsequently Berge, the corresponding author, and I were asked to prepare two papers to be published back to back, and to get back to the editorial offices of the journal only after we had seen our final versions and had no further comments to make. Thence ensued a very friendly email correspondence between Berge and myself, which resulted in ESW's "Quantum erasure in double-slit interferometers with which-way

detectors"[5] and my "Objectivity, retrocausation, and the experiment of Englert, Scully, and Walther"[6].

We agreed more or less on what was wrong, but we couldn't quite agree on what was right. On one hand, Berge *et al.* would insist that when the experimenters find the photon in the first resonator, "they *know* that the atom went through the first slit.... The photon stored in the resonators supplies genuine WW [=which-way] knowledge." On the other hand, they would insist that saying "this atom went through the first slit" is "not a statement about the atom's past.... the properties 'went (or will go) through the first slit' or 'went (or will go) through the second slit' are not actual, but only potential, until a measurement result establishes which one is the case." They resolved this apparent contradiction by pointing out that "physics is always about as-if-realities. Physics deals with the phenomena that we perceive and which we can communicate about. An imagined reality beyond our perception... is the business of philosophers."

Being a philosopher at heart, I would insist that finding the photon in the first resonator does warrant the claim that the atom *really* went through the first slit. At the same time I fully agreed with Berge *et al.* that the following assumption "flies in the face of the fundamental quantum-mechanical indeterminacy": "'went (or will go) through the first slit' is an objective property possessed by the atom to begin with..., a property that we are merely recognizing when we find the photon in the first resonator." I resolved the apparent contradiction by pointing out that this is not what I mean by saying that the atom *really* went through the first slit. Finding the photon in the first resonator does not warrant the claim that the atom went through the first slit *and that it would have done so even if the photon had not been detected.* The atom went through the first slit *because* the photon was found in the first resonator. The way I see it, properties in the quantum domain are possessed if and only if their possession is indicated by an actual event or state of affairs. In the quantum domain, to *be* is to be *measured.* If what happens there depends on what happens or is the case in the macroworld, what happens in the quantum domain at an earlier time can depend on what happens in the macroworld at a later time. The implicit claim is not that we can change the past but that we can contribute to creating a past where there was none.

I think that both attitudes are legitimate, except that my use of the term "retrocausa-

tion" was unfortunate. If a property is not actual until a measurement result establishes that it is (or was) possessed, a more appropriate term would be "retroactualisation."

I also believe that humankind's quest for knowledge has two important aspects. One is lab-oriented. It has produced amazing feats of ingenuity and the most unexpected experimental data. The other is armchair-oriented. It seeks to situate the experimental data in a larger narrative, one that can deal with such humanly important issues as the reality of qualities and values, which cannot be addressed by the quantitative and value-free methods of empirical science.

This quest, I came to realize, can hardly succeed without abandoning that classical sleight of hand which consists in the reification of calculational tools. The fundamental theoretical framework of physics is a probability calculus, and the events to which (and on the basis of which) it serves to assign probabilities, are measurement outcomes. We now have enough no-go theorems to conclude that there is no physical mechanism or natural process by which the correlations between measurement outcomes can be explained. If there is something that is responsible for the existence of the universe, and if, as I believe, its creative power is unlimited, then this should not come as a surprise, for it would be self-contradictory to explain the working of an infinite power in terms of physical mechanisms or natural processes. If this works under constraints, we need to know to what end, and we need to know why the constraints have the particular form that they do. The answer of the second question will of course depend on the answer to the first.

In 2002, I published a paper[7] in which I argued that the Standard Model plus General Relativity are preconditions of the possibility of an "interesting" world, defined (by E. Squires[8]) as one that contains chemistry, and suggested that the validity of these theories may be required for the very consistency of quantum mechanics: quantum mechanics presupposes the macroscopic events which it correlates; the existence of these events requires a sufficient variety of chemical elements; and this implies the validity of the Standard Model and General Relativity, at least as effective theories. In another paper[9], published in the *International Journal of Quantum Information*, I derived quantum mechanics from the existence of reasonably stable objects that "occupy space" while being composed of finite numbers of objects that do not "occupy space." I suspect it was mostly this paper, and the criticism it contained of the standard axiomatic approach, that led to my second encounter

with Berge. (Axioms are supposed to be clear and compelling. The standard axioms of quantum mechanics are anything but.)

In November 2008 I received an email from a Senior Editor of World Scientific Publishing, informing me that they are

> "looking for suitable author(s) to write book(s) in the field of quantum mechanics. We were very impressed with your extensive publication and your strong background in this field. Prof. Berthold-Georg Englert, National University of Singapore, Managing Editor of the International Journal of Quantum Information, also recommended to us that you might be the right person for this book project."

Not bad for a university dropout who has not seen the inside of a physics laboratory since his student days at the university of Göttingen in the mid-Seventies! This is how, in 2011, I came to publish a textbook with the preposterous title *The World According to Quantum Mechanics: Why the Laws of Physics Make Perfect Sense After All*. It is based on a philosophically oriented optional course of quantum physics, which I have offered since year 2000 to higher secondary and undergraduate students at the Sri Aurobindo International Centre of Education in Pondicherry. So far the book has copped three reviews at Amazon.com, all unsolicited and five-star. It is probably the only book with a five-star review that says, "You will hate this book".[1] Thank you, Berge, and Happy Birthday to you! I look forward to meeting you in person for the first time.

References

[1] U. Mohrhoff, Restoration of interference and the fallacy of delayed choice: Concerning an experiment proposed by Englert, Scully and Walther, Am. J. Phys. 64, 1468–1475 (1996)

[1] Excerpt: "The way this book covers the two slit experiment everything falls into place and makes perfect sense. There is no wave particle dualism, just the naked necessity of a probabilistic regime. It is so simple. Painfully obvious. Easy to grasp with just a minimum of mathematical rigor. It boggles the mind that QM has not been understood this way from the get go. This feels like 20/20 hindsight writ large. . . . If you've been trying to make sense of QM you will hate this book. It'll make you feel stupid for not having been able to see this all along. Time to eat some humble pie."

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[3] U. Mohrhoff, What quantum mechanics is trying to tell us, Am. J. Phys. 68, 728–745 (2000)

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[5] B.-G. Englert, M.O. Scully, and H. Walther, Quantum erasure in double-slit interferometers with which-way detectors, Am. J. Phys. 67, 325–329 (1999)

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[9] U. Mohrhoff, Quantum mechanics explained, Int. J. Quant. Inform. 7(1), 435–458 (2009)