RECOLLECTIONS OF JOHN BELL

MICHAEL NAUENBERG
DEPARTMENT OF PHYSICS
UNIVERSITY OF CALIFORNIA, SANTA CRUZ

It is a pleasure to contribute to this anthology some of my recollections of John Bell.

I first met him at SLAC, when we were visitors during 1964-65 when he was on leave from CERN, and I was on leave from the Columbia University Physics Department. Soon I found that we had a common interest in the foundations of quantum mechanics, and we had lively discussions on this subject. We were concerned with the 'reduction of the wave packet' after an experiment in quantum mechanics has been completed, and wrote a tongue in cheek article on this subject for a *festschrift* in honor of Vicki Weisskpof [1], stating that

> "We emphasize not only that our view is that of a minority but also that current interest in such questions is small. The typical physicist feels that they have long been answered, and that he will fully understand just how, if ever he can spare twenty minutes to think about it"

Now, 50 years later, this topic, known as the *measurement problem.* has become the source of numerous articles representing as many different viewpoints. At the time, however, I confess that I didn't realize that the main flaw in John von Neumann's presentation of this problem was his assumption that a measuring device can be represented by a pointer with only two quantum states. Actually, a measuring device must be able to *record* the outcome of an experiment, and for this purpose it has to have an enormous number of quantum states leading to an irreversible macroscopic transition in this device. A correct discussion of the measurement problem was given, for example, by Nico van Kampen [3], but recently he told me that he was unable to persuade Bell, who continued to be concerned about this problem for the rest of his life. Indeed, shortly before he died, he wrote an article entitled "Against Measurement", where he continued to argue that this problem constituted a fundamental flaw in quantum mechanics. Concerning his disagreement with van Kampen, he wrote:

> Let us look at one more good book, namely Physica A 153 (1988), and more specifically at the contribution: 'Ten theorems about quantum mechanical measurements', by N. G. van Kampen. This paper is distinguished especially by its robust common sense. The author has no patience with '. . . such mind-boggling fantasies as the many world interpretation . . . " . He dismisses out of hand the notion of von Neumann, Pauli, Wigner that 'measurement' might be complete only in the mind of the observer: '. . . I find it hard to understand that someone who arrives at such a

> conclusion does not seek the error in his argument' . For vK '. . . the mind of the observer is irrelevant . . . the quantum mechanical measurement is terminated when the outcome has been macroscopically recorded . . . " . Moreover, for vK, no special dynamics comes into play at 'measurement': '. . . The measuring act is fully described by the Schrodinger equation for object system and apparatus together. The collapse of the wavefunction is a consequence rather than an additional postulate . . . " .[4]

Bell concluded that van Kampen's kinematics "is of the de Broglie-Bohm 'hidden variable' dual type" but this claim is not justified. One of the most eminent physicists of the *20-th* century, Rudolph Peierls, and a pioneer in the development of quantum mechanics, who had supervised Bell when he was his graduate student, also disagreed with him on this issue. In a reply to Bell's article entitled "In Defence of Measurement" , he wrote

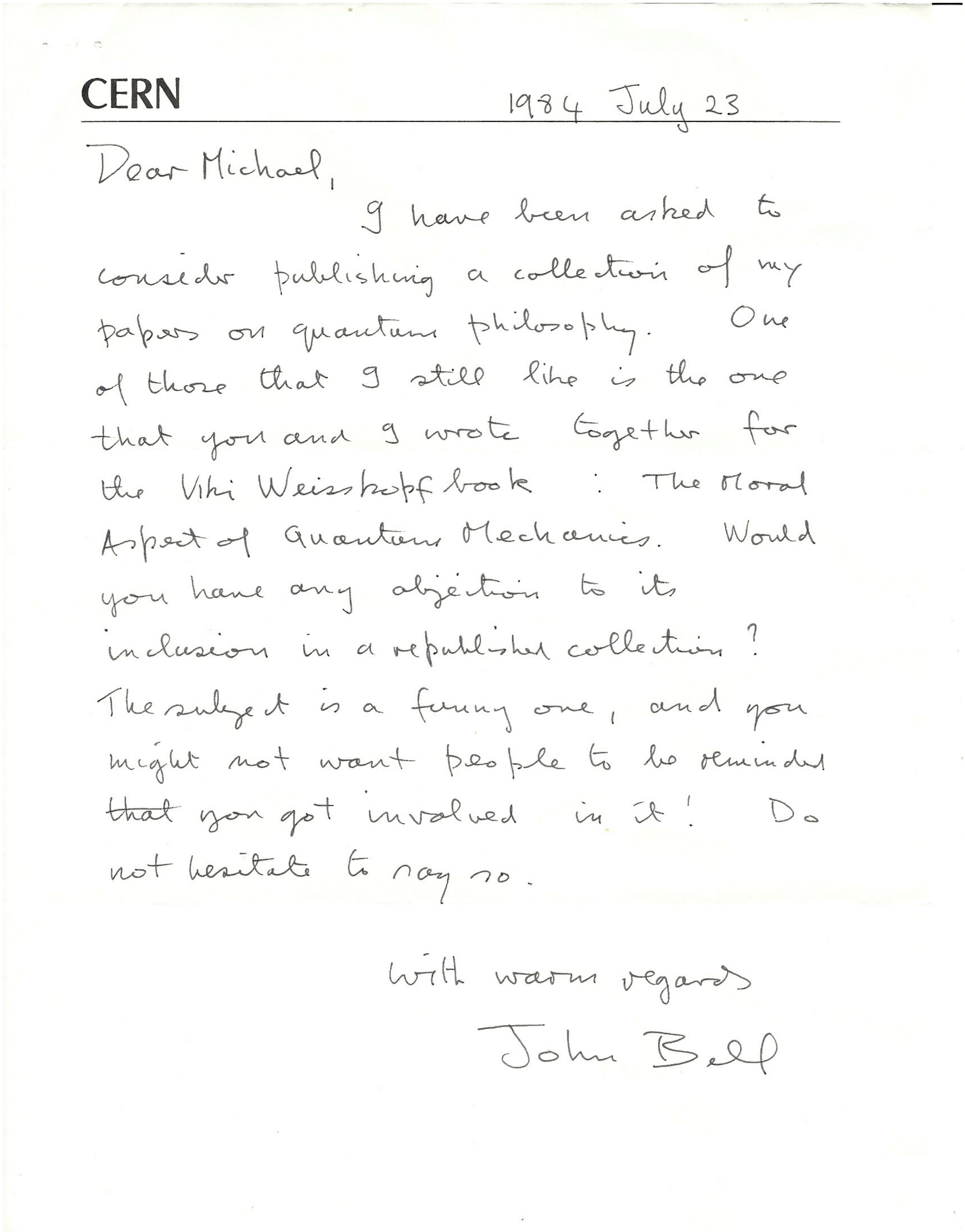
> He [Bell] regarded it as necessary to have a clearly formulated presentation of the physical significance of the theory without relying on ill-defined concepts. I agree with him that this is desirable, and, like him, I do not know of any textbook which explains these matters to my satisfaction. I agree in particular that the books he quoted do not give satisfactory answers (I assume that they are fairly quoted; I have not re-read them). But I do not agree with John Bell that these problems are very difficult. I think it is easy to give an acceptable account, and in this article I shall try to do so. I shall not aim at a rigorous axiomatic, but only at the level of the logic of the working physicist.[5]

But this "logic" is what Bell called proof by FAPP=for all practical purpose.

In 1984 John received an invitation from Cambridge Univ. Press to publish a collection of this papers on quantum philosophy, and he asked me whether I had any objections to include in it our joint paper on the measurement problem. By then I had lost interest in this subject, but I agreed when he wrote to me that "one of those [papers] I still like is the one that you and I wrote together for the Viki Weisskopf book". A copy of his letter is reproduced in Fig. 1. because it reveals his characteristic sense of humor when he ended with ". . . you might not want to remind people that you got involved with this". He was right.

In the late 1960's, I often met Bell during my frequent visits to CERN. We regularly had lunch with other physicist at the CERN cafeteria, and in retrospect, it is remarkable that during that time, Bell never brought up his seminal theorem that quantum mechanics can not be reproduced by local hidden variables. I think that a plausible reason was that some of our common friends and lunch companions at the time, that included Martinus Veltman and Jack Steinberger (both later received the Nobel Prize for their contributions in particle physics), did not express any interest in this subject. Recently, I asked Veltman for this recollections, and he responded:

> Frankly, I never discussed hidden variables with John. In 1963 both John and I were at SLAC, where he wrote his famous paper. I was not interested in hidden variables at all; John once told me that he was trying to definitely



CERN

1984 July 23

Dear Michael,

I have been asked to consider publishing a collection of my papers on quantum philosophy. One of those that I still like is the one that you and I wrote together for the Viki Weisskopf book : The Moral Aspect of Quantum Mechanics. Would you have any objection to its inclusion in a republished collection? The subject is a funny one, and you might not want people to be reminded ~~that~~ you got involved in it! Do not hesitate to say so.

With warm regards

John Bell

FIGURE 1. A letter from John Bell to the author

> silence Jauch who was apparantly trying to convince John about hidden variables. I remember saying that I gladly left it to him, and we collaborated on other things . . .

But Bell's comments in high energy physics were always appreciated. For example, Veltman and I discussed with him some issues related to current algebra and gauge variance which later led to an article by Bell on this subject [6]. I also recall that at the time we were both interested in the decay of neutral K meson, and Bell wrote an excellent review article on this subject with Steinberger [7]

In the 1980's, Bell and I attended a meeting of the American Academy of Arts and Sciences in Boston, Mass. One of the presentations was given by Alain Aspect on his experiment on two photon spin correlations of an entangled state of total spin zero, demonstrating that these correlations were in agreement with quantum mechanics, and in violation with Bell's inequality based on local hidden variables [8]. Bell had bought two tickets to a special retrospective exhibit of Renoir's paintings at the Boston Art Museum, and since his wife Mary could not come, he invited me to join him. While walking along the galleries he told me that a few years earlier, Alain had come to visit him at CERN to discuss his plan for an experiment to test his inequality. Then Bell asked him whether he had tenure, and when Aspect responded negatively, Bell tried to discourage him from pursuing the experiment, fortunately without success.

Apparently, Bell did not encourage experimental tests of his famous inequality, but neither did other physicists at the time. John Clauser, a graduate student in Astronomy at Columbia University, who had stumbled on Bell's paper in the Physics library, became very excited about the possibility to carry out an experiment that could possibly disprove the universal validity of quantum mechanics. But he was strongly discouraged by his thesis adviser, Pat Taddeus, who told him that such an experiment would be a waste of time. Then Clauser wrote to Bell, asking him what the thought about doing such an experiment, who responded:

> In view of the general success of quantum mechanics, it is very hard for me to doubt the outcome of such experiments. However, I would prefer these experiments, in which the crucial concepts are very directly tested, to have been done, and the results on record.
>
> Meanwhile there is always the chance of an unexpected result, which would shake the world [9]

Clauser also visited Richard Feynman at Cal Tech to discuss his proposed experiment, but Feynman told him that he would be waisting his time.

Earlier, a former student of Wigner, Abner Shimony, who was in the Princeton philosohy department, had also become interested in an experimental test of Bell's inequality, and when he read an abstract that Clauser had submitted on this subject to an APS meeting, contacted him. Afterwards, together with his student, Michael Horne, and with Francis Pipkin's student, Richard Holt, they collaborated on a paper that discussed in detail how such an experimental test could be performed [10]. After graduating from Columbia University, Clauser obtain an astrophysics post-doctoral position with Charles Townes at UC

Berkeley, but succeed in convinced him that his proposed atomic physics experiment was worth doing. As luck would have it, Gene Commins, with his student Carl Kocher, had carried out an experiment measuring the polarization correlation between two entangled photons in a state of spin zero from the decay of Calcium atoms. But they had only considered two special cases where the polarization analyzers where either aligned or orthogonal to each other [11]. Together with Commins' graduate student, Stuart Freedman, Clauser continued their experiment by building polarization analizers that could be rotated at an arbitrary relative angle, and carried out the first experimental test of Bell's inequality. As is well known, they obtained results in good agreement with the predictions of quantum mechanics [12], Twelve years later, after Aspect presented his results, Feynman also changed his mind, and after a seminar Aspect gave at Cal Tech on his experiment, Feynman wrote to him that " . . . your talk was excellent"[13]

The last time I saw Bell was in the summer of 1989, when he invited me to present my work on the motion of wave packets in a Coulomb potential [14] at the weekly CERN theory seminar. During this talk, I particularly called his attention that the wave packet gave a distribution that is very similar to that of a classical ensemble of particles rotating around the center of force. But the particles in such an ensemble spread, and when the head of the packet catches up with its tail, which occurs after a well defined interval of time that depends on the mean principal quantum number of the wave packet. Then the quantum-classical correspondence ceases to be valid due to wave interference in quantum mechanics. After the seminar, I suggested to Bell that he submit a proposal to the Santa Barbara Institute of Theoretical Physics (ITP) for a workshop on problems in the foundations of quantum mechanics. He agreed, provided that would do the leg work. At the end of our conversation he walked out with me through the long corridors of CERN until we reach the parking lot. That was the last time I saw him; he died unexpectedly a few months later.

Outside the community of experts in his field, recognition of Bell's seminal insights has been slow in coming , but this is changing now. In particular, Belfast, the Irish city where he was born and first educated, has dedicated the entire month of November 2014 to celebrate the 50th anniversary of the publication of his famous theorem. To honor Bell, Belfast also plans to re-name various streets and buildings with his name.

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