‘Shut up and calculate!’

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I

‘*Shut up and calculate*!’ – this phrase has acquired wide currency in and outside the quantum community, and is supposed to express the attitude of the typical working quantum physicist confronting people outside the community (or, may be, even ones *belonging to it*) who express doubts or anxiety over what quantum theory really *means*.

The phrase is widely believed to have been coined by the great Feynman, known for his irreverence to lofty but empty ideas and thoughts. In fact, it originated in an article by David Mermin, the well known physicist and an author of great repute, which appeared in the journal *Physics Today*, in its April, 1989 issue: *If I were forced to sum up in one sentence what the Copenhagen interpretation says to me, it would be “Shut up and calculate!”*

Later, Mermin came to distance himself somewhat from this seemingly dismissive stance toward the Copenhagen interpretation of quantum theory associated with the names of Bohr, Heisenberg, Born, and Pauli, among others, as he was to write in the May, 2004 issue of the same journal: *In the intervening years, I have come to hold a milder and more nuanced opinion of the Copenhagen view… .*

In this May, 2004 article of his, Mermin, in a typically witty style, pointed out that it was he, and not Richard Feynman, who had coined the phrase that was later to catch the imagination of so many people in and around the quantum community, adding that he, Mermin, was not really proud of having had done so, and calling the phrase a piece of ‘wretched witticism’ (*…not so terribly bon mot.…*) .

However, this disclaimer of Mermin’s notwithstanding, the phrase remains a potently provoking one and will certainly linger and gain in popularity in the field of the growing discourse on the meaning of quantum theory and on the world view that it may (or may not) lead to, precisely because it can mean different things to different people, and that too *in contrary ways*: regardless of the author who would, perhaps, not be unhappy to disown his own brainchild, the popularity of the ‘child’ is destined to grow.

Here are two distinct points of view that the pithy phrase can possibly be assumed to represent.

First, it can represent a point of view laden with arrogance, with the quantum physicist browbeating others who hesitate to tread the quantum path out of confusion and dismay, and who prefer to be convinced of the soundness of the quantum world view on philosophical grounds first. The physicist is here blatantly issuing a decree against what appears to him to be worthless philosophical speculation.

Or – and this is about the *other* possible point of view that the physicist may subscribe to - this same phrase can be assumed to represent a different and more patient attitude – one where she urges others to base their philosophical speculations on an adequate working knowledge of the subject, acquiring an ability to *calculate*, or to appreciate the deep and massive content of what they, the quantum physicists, calculate with astounding effectiveness and precision, and with an unwavering loyalty to the fundamental working principles of the theory. They may not be wrong in their reading that, it is precisely because of their indifference toward fruitless philosophical speculation that they keep on producing voluminous and marvelous results bearing testimony to the remarkable merit of quantum theory.

While the two points of view appear to be quite distinct, they need not be mutually exclusive since the same quantum physicist can, and often does, hold both of these, expressing one or the other as she confronts people with differing mental make-ups. Moreover, there does not seem to be a clear-cut line of demarcation between the two since it is not so easy to locate where arrogance ends, giving way to an uncompromising passion to explore, by means of ingenious calculations, the overwhelming effectiveness of the few basic working principles of quantum theory.

And who can deny that even well intentioned people, in their zeal to discover some basic flaw in the way quantum theory looks at the workings of nature, can indulge in exasperatingly endless discourse where quantum theory is examined at a *meta*-level, with little attention paid to the basic question as to how and why it works with such uncanny effectiveness? Why should one not grant the quantum physicist the right to put a stop to such fruitless blabber, most of which is *not even wrong*, as Wolfgang Pauli would put it?

It seems that the physicist should indeed have that right, if only…. . If only it were not a fact that the most precious gems often lay buried in heaps of earthy matter, to be discovered only by patient and diligent exploration.

In spite of the success of quantum theory in producing astoundingly effective results, based on a few working principles of a mathematical nature, without any apparent footing in an accepted world view spanning a larger canvass, or perhaps, *because of* this very success, people have always staked their minds, and their hearts, at making a *meaning* of quantum theory. And they will, for years to come.

Witness, for instance, the proliferation of the many ‘interpretations’ of quantum theory, where scientists and philosophers attempt to come to terms with what appear to be bizarre - almost surreal - aspects of the theory when looked at from the familiar classical world view of physics. Even the great and towering personalities in quantum theory such as Bohr, Heisenberg, Schrödinger, Pauli, Einstein, Bell, and Feynman – indeed, *all* the great minds in quantum theory - were driven by their unquenched aspiration to *understand* what this theory really means. They

looked for a broader philosophy for making sense of quantum theory, but they also had the *ability to calculate*.

Not everybody can be an Einstein, or a Bell, or a Feynman, but people trying to 'make sense' of quantum theory would do well to heed the admonition of the physicist, delivered from the more positive of the two points of view mentioned above, which in essence tells them to refrain from philosophical speculations without a serious engagement with the *content* of the theory.

What, then, of the *common man* making a nuisance of himself trying to 'understand quantum theory' and shouting in disgust when the lofty mathematics of quantum theory fails to satisfy him? Is the common man then going to be banned from all discourse pertaining to quantum theory and its possible meaning? It is most definitely a risky business trying to answer this question in the affirmative.

Because, ultimately, it is the wisdom of the common man that gets distilled into that almost supernatural intellect of an Einstein or of a Feynman. What the common man knows *implicitly* of the workings of Nature ultimately finds expression in the abstract mathematics of the laws of physics through an unseen process of cumulative upward percolation where myriads of molecules are drawn up by cohesive forces exerted by myriads of others.

It is no use trying to browbeat the common man into silence. The one thing common to the common man and to the Einsteins and the John S. Bells is that they *will not shut up*. And the one great difference between the two is that while the Einsteins will *calculate*, the common man will *not*.

There is a growing feeling that *quantum theory needs no interpretation distinct from its content* because it makes the irreducible statement to the effect that *the external reality may exist as an entity independent of our senses, but we can make meaningful statements about it only through what we learn through observations and measurements,* the results of the observations being the ultimate thing that we can speak of meaningfully. This, of course, does not mean that the world is a construct of the observer, but is at the same time quite distinct from the pre-quantum realist world view, an allegiance to which make people pine for a reconciliation between quantum theory and their dearly held conceptual universe.

While some form or other of this great urge for a reconciliation activates the minds of the common man and of the Einsteins, the Bohrs, and the Bells, it has been the latter that have greatly contributed to the progress of quantum theory through their commitment to *calculation*, through untiring and patient work of a technical nature while the former seems only to make a nuisance of himself. Still, one does never know how the myriads of molecules of wisdom move up by percolation and by unseen forces of cohesion…. from the common man to the stalwart….
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II

This brings up the question of the role played by the Copenhagen interpretation of quantum theory: to what extent has the Copenhagen interpretation been responsible for the exquisite theoretical and practical achievements of quantum theory? I do not know much of the Copenhagen interpretation. However, it seems that what goes by the name of this 'interpretation' (there have been a number of others to follow) can be described as a nebulous and inhomogeneous body of ideas and explanations to which several of the pioneers contributed in a kind of half-hearted attempt at giving quantum theory a philosophy of its own, and at convincing critics that quantum theory was not founded on the quicksand of bad philosophy. The principal *scientific* content in the 'interpretation' was to address the question as to how an observation, which is basically a *classical* operation, can be accommodated in a *quantum* theoretic description of the world.

The mind of Niels Bohr was greatly occupied with this question and he advanced quite elaborate arguments in trying to clarify the issue, but the question itself remained unresolved and it may not be an exaggeration to say that the central issue of the so-called *collapse of the wave function*, seemingly caused by the quantum system being subject to the classical act of observation, lies at the root of the proliferation of so many 'interpretations' other than the one with its name associated with the city of Copenhagen.

It may not be far from the truth to state that the prestige and authority of Niels Bohr, taken together with the exchanges between Bohr and Einstein, especially with Bohr's response to the famous Einstein-Podolsky-Rosen (EPR) paradox, contributed to the general allegiance of the working physicist to what in his perception was an authoritative philosophical umbrella to the emerging and blossoming quantum theory. The comparatively poor philosophical grounding of the physicist and the apparently deep and lofty philosophical issues embodied in the Copenhagen discourse gave him a handle to get on with his bread and butter work in quantum theory without the distraction of needless philosophy. Hence the perception, that the Copenhagen interpretation asks the world to 'shut up and calculate'.

With the passage of time, the Copenhagen interpretation, which started as a sincere and well intentioned attempt at making sense of quantum theory, turned into something like a party line where people towed the line without even bothering to follow what the interpretation really meant. Despite all the rival interpretations that emerged, it was the Copenhagen interpretation that acquired the status of a *paradigm* in quantum theory.

III

Ever since Thomas Kuhn introduced the concept of a 'paradigm' in the context of history and methodology of science, there has been a vast literature on the subject where Kuhn's idea has been hailed as a great and immensely useful one on the one hand, and a wretched and harmful view of science on the other. Regardless of the polemics, however, quantum theory seems to me to be a remarkable instance where entire generations of scientists have joined hands in taking the subject ahead in a rare spirit of joyous adventure by committing themselves to the spirit of *calculation*, paying allegiance to a central paradigm and refusing to get diverted in attempts to explore in any major way the possibility of alternatives.

And the one important point I want to make here is that the Copenhagen discourse did *not* provide for this paradigm, though it did a great deal in initially making people committed to what it propounded. As I see it, the role of a paradigm in the true sense was played by a couple of textbooks – one by Paul Dirac (1930) and the other by Von Neumann (1932). Together, these two books set forth in remarkably clear terms the basic principles of quantum theory, and provided a precise mathematical framework in which future generations of physicists would find the guiding principles for their own *calculations*.

Both the two books were completely indifferent toward philosophical issues raised by Bohr, Schrödinger, Einstein and others, and were brilliant trend-setters in a *precise* formulation of quantum theory in *mathematical* terms because the authors felt that there was no point in half measures where quantum theory was concerned, and the need for the day was a set of concrete rules for mathematical calculations. Between them, the two books set forth the basic principles that were so brilliantly being made use of by the likes of Pauli, Schrödinger and Dirac in waves after waves of remarkable papers that were setting the entire world of physics on fire.

Ever since, quantum theory has time and again demonstrated the power of the decree: *shut up and calculate*. Of course, there were people who asked questions. For instance, Feynman asked questions, but mostly he asked those in silence and never rested till he himself provided the answers. John S. bell asked questions, and was not satisfied a bit with the received wisdom but he, too, calculated and gave the world the famous inequality bearing his name that, more than anything else, brought in the information theoretic revolution in quantum theory dating from the nineteen eighties. And ironically, the emerging generation of computer scientists

and physicists went ahead with the revolution with the same old paradigm in command, the paradigm that Dirac's and von Neumann's books had sculpted out some half a century earlier. The notion of quantum entanglement, introduced as a 'spooky' concept by EPR and by Schrödinger in the nineteen thirties, was revived by these young physicists as one of central importance in quantum theory, but this time with no ghostly specter haunting them. Entanglement was now a bread and butter subject, certainly an enigma, but equally certainly an earthly one, to be cleared up by the power of *calculations*, and not with high philosophy or with a shivering awe one feels at seeing an apparition. And a great new vista got opened up. In short, - once again - *shut up and calculate.*

But they will not shut up. They will clamor for a World View. They will never stop shouting that quantum theory must be made to *make sense*. And who knows? Molecules of wisdom will move upwards…. . And some day, quantum theory *may* make sense.

Suggested reading:

1. N. David Mermin: *Could Feynman have said this?*

   Physics Today, May 2004, Vol. 57, Issue 5, p 10

   DOI: http://dx.doi.org/10.1063/1.1768652

2. N. David Mermin: *What's wrong with this pillow?*

   Physics Today, April 1989, Vol. 42, Issue 4, p 9

   DOI: http://dx.doi.org/10.1063/1.2810963

3. C. A. Fuchs and Asher Peres: *Quantum Theory Needs No 'Interpretation',*

   Physics Today, March 2000, Vol. 53, Issue 3, p 70

   DOI: http://dx.doi.org/10.1063/1.883004

4. N. P. Landsman: *Between classical and quantum,* at

   http://arxiv.org/pdf/quant-ph/0506082v2.pdf

Kolkata, 13 May, 2014.