The physicist Sheldon Goldstein

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This meeting is honoring Sheldon Goldstein on the occasion of his 60th birthday. It is on rare occasions like this that one can speak not only about scientific papers and technical results but also about the person, the feu sacré within the scientist. Personal words of admiration and friendship may be delivered, but one may also explore the physical and cultural environment which takes at least some responsibility for the questions and aims the scientist strives for. The sociology of physics determines the categories of importance and judgement of quality of scientific work. Over the past century a strong non equilibrium has developed between metaphysical understanding and technical work, highly weighting the production of technical results. It is rare nowadays that a physicist's life work leads one to the association with the famous inaugural lecture of the the German poet Friedrich Schiller, as the scientific life of Sheldon Goldstein does. Freely adapted to this context this amounts to: What is and to which end do we study physics[1]?

I start however with a question which seems much more urgent.

1 What is special about the 60th birthday?

While for the number 6 various mystical and geometrical meanings may easily come to mind, 10 times 6 does not lead to anything meaningful besides being

[1](Was heißt und zu welchem Ende studiert man Universalgeschichte? Friedrich Schiller in Jena 1789)

the number of seconds in a minute and the number of minutes in an hour. Maybe turning 60 makes you feel like an hour or a minute has passed since you happily realized that you are alive and thinking. But would that call for a celebration? Is 60 a historical age? Sokrates died happily (so it is reported) at the age of 61 but that's a random fact. Is it a biblical age? Of Adam and Eve only Adams age seems to be known–960 years–and about his descendant Methuselah one reads in Moses chapter 8: "And Methuselah lived, after he begat Lamech, seven hundred and eighty-two years, and begat sons and daughters." On this scale 60 years is childish. But after Methuselah the population on earth did not evolve to the liking of God for Moses continues: "And the Lord said unto Noah: My Spirit shall not always strive with man, for he shall know that all flesh shall die; yet his days shall be an hundred and twenty years; and if men do not repent, I will send in the floods upon them."

There you are then. 120 is the biblical age and 60 is half the biblical age and that is worth the celebration.

2 Why should Sheldon Goldstein be honored in excess of "normal" birthday celebrations?

Max Planck, surveying his own career in his scientific autobiography[2] sadly remarked that: "A new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grows up that is familiar with it." This certainly agrees well with my own experience but is it true? There is a remarkable exception to which we come in a minute. There are various other questions which arise with Planck's empirical statement. Why should it be so, that scientific truth does not triumph in discussions? I shall not try to pursue this question any further except remarking that a scientist must possess two conflicting qualities at the same time: The scientist must be open to new ideas, which may even seem crazy at first sight and at the same time the scientist must reason, in other words, the scientist must preserve sanity in science. It is only human that most scientists will hold fast to what seems secured as reasonable by long education and majority views.

[2]Scientific Autobiography and Other Papers, Max Planck, Greenwood Pub Group (June 1968)

A second question is: What or who keeps the new scientific truth alive until all opponents have died away and how can a new generation get familiar with it? The importance of this question increases with the number of scientists which occupy earth simultaneously, a number which has exploded since Planck's time. A new scientific truth must first be able to surface and it has to be prevented from drowning again within the ocean of results, new ideas, crazy ideas, technical advances, crazy technicalities, crazy philosophy. The new scientific truth which concerns us here, because it is intimately connected with the physicist Sheldon Goldstein emerges from the question: What is it that quantum mechanics is about? Quantum Mechanics took about 30 years to be developed, beginning with Planck's discovery of energy quanta in black body radiation in 1900 and essentially completed with the works of Schrödinger and Heisenberg in 1926.

But here is something really surprising and a counterexample to Planck's lament. It only took, and the emphasis is on "only", 15 years to turn physics upside down, counting the time span from Bohr's atomic model in 1913 until the quantum theory of Heisenberg and Schrödinger. The majority view on Quantum Mechanics was almost immediately adopted from the so called Copenhagen interpretation of the theory as formulated in 1926. It is still the majority view among most contemporary physicists, who by their everyday life cannot spare the "twenty" minutes to question the Copenhagen authority. It is captured by the following quotes:

Niels Bohr[3]: "If quantum mechanics hasn't profoundly shocked you, you haven't understood it yet.... It is wrong to think that the task of physics is to find out how Nature is. Physics concerns what we say about Nature. ...Your theory is crazy, but it's not crazy enough to be true." Opponents of this almost coquettish new tone were Einstein and Schrödinger but they stood alone for many decades. One generation later Feynman writes[4]: "Electrons, when they were first discovered, behaved exactly like particles or bullets, very simply. Further research showed, from electron diffraction experiments for example, that they behaved like waves. As time went on there was a growing confusion about how these things really behaved —- waves or particles, particles or waves? Everything looked like both.

This growing confusion was resolved in 1925 or 1926 with the advent of the correct equations for quantum mechanics. Now we know how the

[3]http://www.brainyquote.com/quotes/authors/n/niels-bohr.html

[4]Richard P. Feynman, The Messenger Lectures, 1964, MIT

electrons and light behave. But what can I call it? If I say they behave like particles I give the wrong impression; also if I say they behave like waves. ...Your experience with things that you have seen before is incomplete. The behavior of things on a very tiny scale is simply different. ...There is one simplification at least. Electrons behave in this respect in exactly the same way as photons; they are both screwy, but in exactly in the same way.

The difficulty really is psychological and exists in the perpetual torment that results from your saying to yourself, "But how can it be like that?" which is a reflection of uncontrolled but utterly vain desire to see it in terms of something familiar. ... There was a time when the newspapers said that only twelve men understood the theory of relativity. I do not believe there ever was such a time. ...On the other hand, I think I can safely say that nobody understands quantum mechanics. So do not take the lecture too seriously, feeling that you really have to understand in terms of some model what I am going to describe, but just relax and enjoy it. I am going to tell you what nature behaves like. If you will simply admit that maybe she does behave like this, you will find her a delightful, entrancing thing. Do not keep saying to yourself, if you can possible avoid it, "But how can it be like that?" because you will get 'down the drain', into a blind alley from which nobody has escaped. Nobody knows how it can be like that."

This all sounds crazy, actually much too crazy for having a chance to triumph in discussions. There is no argument whatsoever why the description of nature must be crazy. Because nobody knows how to do it? Try harder! There is simply no light to be seen. Let us hear Heisenberg on this[5]: "The Copenhagen interpretation of quantum theory starts from a paradox. Any experiment in physics, whether it refers to the phenomena of daily life or to atomic events, is to be described in the terms of classical physics. The concepts of classical physics form the language by which we describe the arrangements of our experiments and state the results. We cannot and should not replace these concepts by any others ... we cannot and should not try to improve them... A real difficulty in the understanding of this interpretation arises, however, when one asks the famous question: But what happens 'really' in an atomic event?.... It is of course tempting to say that the electron must have been somewhere between the two observations and that therefore the electron must have described some kind of path or orbit even if it may

[5]Werner Heisenberg: Physics and Philosophy, 1958; Chapters 3 (Copenhagen interpretation)

be impossible to know which path. .... Any attempt to find such a description would lead to contradictions; this must mean that the term 'happens' is restricted to the observation." When all is said and done the argument is simply this: **You should not ask what is going on.** Isn't it astounding that such a religious dogma established itself in a very short time and prevails–as I said–until today? It did so on half baked superficial arguments which no student of physics should be allowed to get through with. Why that happened is a question which I shall not try to answer. It is a question which historians must work out in the future. To summaries succinctly: the question which once defined physics, namely " What is really going on?" was banned from physics.

But there is a new scientific truth which does suffer the fate Planck described. The new scientific truth is that there is no reason why the physical description of nature should be insane, there is no reason for believing that it is impossible to say what's going on. Because: How can it be like that? has a simple straightforward answer. The new scientific truth is almost as old as quantum mechanics: In 1927 de Broglie put forward the idea to explain "how it can be like that", and David Bohm (unaware of de Broglie's attempt) formulated in 1952 the complete theory (which could have been completed already in 1927) telling in most simple terms what is going on. John Bell, most famous now for the formulation of Bell's inequalities and perhaps the leading expert on foundations of quantum mechanics in the second half of the last century, became one of the most distinguished proponents of Bohm's theory about which he wrote in the 1960's[6]: "But in 1952 I saw the impossible done. It was in papers by David Bohm. Bohm showed explicitly how parameters could indeed be introduced, into nonrelativistic wave mechanics, with the help of which the indeterministic description could be transformed into a deterministic one. More importantly, in my opinion, the subjectivity of the orthodox version, the necessary reference to the 'observer,' could be eliminated. ... But why then had Born not told me of this pilot wave? If only to point out what was wrong with it? Why did von Neumann not consider it? More extraordinarily, why did people go on producing impossibility proofs, after 1952, and as recently as 1978? ... Why is the pilot wave picture ignored in text books? Should it not be taught, not as the only way, but as an antidote to the prevailing complacency? To show us that vagueness,

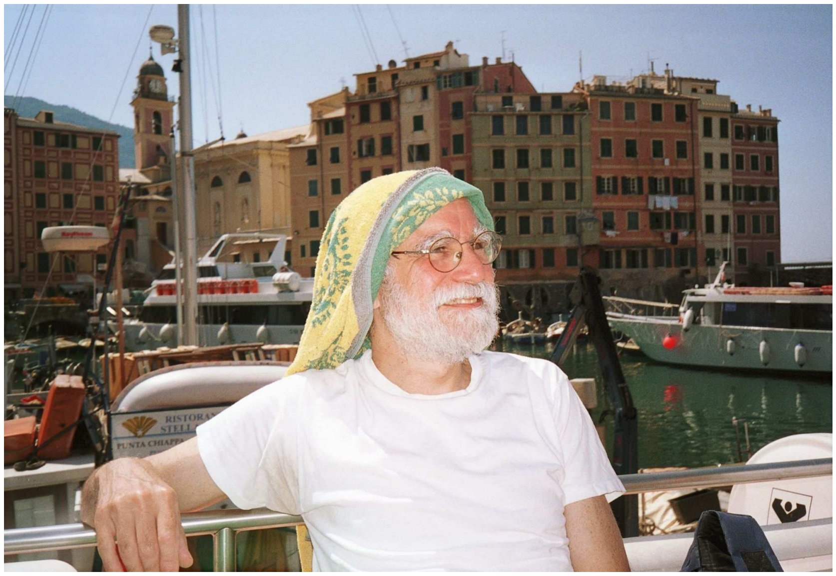
[6] John Bell in *Speakable and Unspeakable in Quantum Mechanics*, Cambridge University Press

subjectivity, and indeterminism, are not forced on us by experimental facts, but by deliberate theoretical choice?"

Sheldon Goldstein, Nino Zanghì and I called Bohm's theory eventually Bohmian mechanics. Bohmian Mechanics is about particles moving and that's about it. It is an utterly trivial completion of quantum mechanics as it adds to the Schrödinger equation the equation of motion for the particles. That equation is straightforward and non conspiratorial and that is a fact. Thus Bohmian mechanics gives to the wave function a precise physical role, namely that of a guiding field, which tells the particle how to move, and it restores sanity to the quantum description of nature.

So here's a new scientific truth–Bohmian mechanics–which in discussions should easily triumph, since there is a bright light shining, but as the presence shows, this triumph might have to wait until the opponents die.

And that brings us back to the second question: What keeps the new scientific truth alive, so that a new generation may see the light and get familiar with? The new scientific truth needs proponents, just like John Bell was, proponents, who are both, physicists in their heart, but mathematically able and sharp to counter the vagueness and fuzziness of quantum orthodoxy, which is so much intertwined with very abstract mathematics. The proponent must be strong in his views and conviction, he must be powerful in his arguments, he must never tire out to fight endlessly, insistently, courageously for the light to be seen, for the new generation to get familiar with the new scientific truth. To keep the new truth from drowning in pragmatism and ignorance. Which physicist is excellent enough, confident enough and strong enough to endure at the end of the day the argument which demolishes with one strike all discussions: "No no, you can't be right, otherwise this new scientific truth would be taught since long and would be the accepted view!" Not only does this demolish sanity it demolishes some of the hope for the future because it is not the old opponents who say that, no, its the young generation, who is supposed to grow familiar with it. It is clear that such a proponent must be a very special person, a rare singularity in the scientific landscape. And there you are then: The principal proponent is Sheldon Goldstein and that is special about him. He has been stirring through stormy waters for almost a quarter century now, never capsizing, never running ashore, and we, his friends and collaborators are deeply grateful to have been allowed as shipmates on this turbulent journey. But mind you, it is not the "Pequod" with Captain Ahab chasing Moby Dick, it is rather an ark loaded with reason.



3 Mathematical Physics

Mathematical Physics became in recent years fashionable. As an outsider one may easily get the picture that every mathematician who is not working in economy or financial mathematics is a mathematical physicist. In my view this is partly grounded in the global misunderstanding that science must be good for technical or industrial developments based on the believe that the latter enhances human happiness.

But what exactly is mathematical physics? I shall choose the diplomatic way answering this by quoting from Sheldon Goldstein's homepage: "No attempt will be made here to explain what mathematical physics is about. There is no general agreement even among the experts. Moreover, this field of research is regarded as somewhat dubious by many physicists. However, the following words of Maxwell are right on target: "The first processes, therefore, in the effectual studies of the sciences, must be ones of simplification and reduction of the results of previous investigations to a form in which the mind can grasp them.(J.C. MAXWELL On Faraday's lines of force)" "

Great physicists among them Galilei and Newton fall into the category of physicists which Maxwell words describes. Since Planck was already mentioned I should remark that Planck was professor of mathematical physics in Kiel.

Sheldon Goldstein's view on mathematical physics is not to have mathematical rigor, it is not to have all the epsilons come out right (if that must be done to get a point clear, then do it!), it is not to rephrase physical contents in bourbakian language, the aim is simply to be clear and precise in technical and non technical notions—the far aim being to say it right! The aim must be to make a sane mind understand what the story is. Be clear on what your views are, be clear about its consequences, be sure that you really mean what you say. Don't be corrupted by fashion and the "zeitgeist". (The spirit of the age). As John Bell says[7]: "... conventional formulations of quantum theory, and of quantum field theory in particular, are unprofessionally vague and ambiguous. Professional theoretical physicists ought to be able to do better. Bohm has shown us a way." To which the Zeitgeist answers[8]: "Thus, unless one allows the existence of contextual hidden variables with very strange mutual influences, one has to abandon them–and, by extension, realism in quantum physics-altogether. "

4 I am a physicist

Letters between scientists reveal often so much more than publications. There exists a short exchange of email letters between Steven Weinberg and Shelly Goldstein. I wish to quote parts from that exchange[9]. Those of you who had email contact with Sheldon Goldstein know that his email address is Oldstein at...That plays a minor role in the following:

"Dear Professor Weinberg,

In your recent response in the NYRB, you ask George Levine, my colleague here at Rutgers, to "suppose that physicists were to announce the discovery that, beneath the apparently quantum mechanical appearance of atoms, there lies a more fundamental substructure of fields and particles that behave according to the rules of plain old classical mechanics." I agree with your point that this should make little difference to our views about culture or philosophy. More interesting, however, is the possibility that it would make little difference to the views of most physicists about physics! In fact, a theory rather roughly corresponding to the substructure that you mention, Bohmian mechanics, that describes a deterministic motion of point

[7] c.l.

[8] Gregor Weihs, The truth about reality, Nature 445, 723-724 (15 February 2007)

[9] http://www.bohmian-mechanics.net/

particles ... from which emerges the entire quantum formalism, including an appearance of randomness and operators as observables..., has been around for more than 40 years, during which time it has been either ignored or misrepresented by the physics establishment. ... This theory completely avoids all the quantum paradoxes, all the mysticism of Bohr and Heisenberg, and replaces it with sharp mathematics..."

Professor Weinberg replied:

" Dear Professor Oldstein,....the basic reason for not paying attention to the Bohm approach is not some sort of ideological rigidity, but much simpler — it is just that we are all too busy with our own work to spend time on something that doesn't seem likely to help us make progress with our real problems. Now I would like to ask you a question. You are not the only person who has recently raised the issue of Bohm's version of quantum mechanics. Why does this have such appeal for some philosophers and sociologists of science?

Sincerely yours, Steven Weinberg "

Response by Sheldon Goldstein:

" Dear Professor Weinberg,.. Although my username is oldstein, my name is actually Goldstein—the one cited in footnote 13 of the article of Jean Bricmont on Prigogine to which you have referred. I have been working on Bohmian mechanics for more than ten years. I am a physicist."

Weinberg's reply:

" Dear Professor Goldstein,

A few days after I sent my previous e-mail message to you, I realized that "Oldstein" is the physicist Shelly Goldstein. I was going to write you to apologize, so I was especially glad to see from your message that I was already forgiven. You are pretty persuasive about Bohmism. Is there a succinct (emphasis on succinct) clear statement of Bohm's theory that I can read?

Best, Steven Weinberg "

5 Bohmian Mechanics

Bohmian mechanics is about particles which move. Given Schrödinger's equation for the wave function ψ the equation of motion for the particles is obvious and deterministic. Obvious, because whichever way you go, you'll end up with the right equations unless you try real hard to avoid them. Deterministic because that's just the way it happens. Determinism is not what Bohmian mechanics wants. In non relativistic Bohmian mechanics that's just how it comes about. Mathematical physics (in Maxwell's sense) comes in to show that all of non relativistic quantum mechanics emerges from the equations of motions of Bohmian mechanics. But here is a question which one might really worry about: Since irreducible randomness is the hallmark of quantum physics, doesn't that contradict any fundamental deterministic physical law?

Ludwig Boltzmann was an exceptional mathematical physicist. He introduced probabilistic reasoning into physics fulfilling the Laplace's prophecy that all random events will when the physical laws are eventually found be deterministic. Boltzmann explained that typical behavior of a physical system which evolving deterministically may nevertheless appear random as if governed by chance. Somehow the light of this scientific truth did not enlighten the 20th century. The idea, to apply Boltzmann's reasoning to Bohmian mechanics did not come to Bohm, Bell however had clearly the right idea, without seeing the need to elaborating it and it needed someone who by chance was just right from his education and scientific work to catch on and to work it all out.

Shelly Goldstein was born August 24th 1947 in Augusta, Georgia. He began his undergraduate studies at Yeshiva University, then went to graduate school (for physics) at Cal Tech and afterwards moved back to Yeshiva University (Belfer Graduate School of Science) where he met Joel Lebowitz. Under Joel's influence Shelly's research was directed towards statistical mechanics and to non-equilibrium statistical mechanics. Before moving to Cornell and then to Rutgers Shelly spend a couple of years at the Institute for Advanced Studies.

Everybody knows Schrödinger's cat, and when I was a student I learned that the question, whether the cat is dead or alive makes simply no sense as long as nobody looks. My generation had little chance arguing with that. Either hang yourself or admit that that question just makes no sense in physics.

The difference between US and Germany was, that with the establishment of the "Third Reich" intelligence was exiled from Germany. Many of the leading physicists immigrated to the US. Among them Wigner who gave a class in Princeton on the foundations of Quantum Mechanics which Shelly attended while staying in Princeton. Wigner, of course, drew from Schrödinger's cat the correct conclusions. It is a problem: The measurement problem. That is all it takes: One person who says it right. Shelly did not have to hang himself and was ready for Bohmian mechanics to find him. It took a detour over stochastic mechanics but more or less in 1987 Shelly Goldstein became a Bohmian. How he found me or I him and how we found Nino Zanghì or he us, is a story which has to wait (fortunately) for a few more years.

In any case, in 1989 Shelly, Nino and I, working already since many years together, met in the IHES (invited by Joel, to whom we are very thankful) and worked out Boltzmann's reasoning for Bohmian mechanics, resulting in the paper: " Quantum Equilibrium and the Origin of Absolute Uncertainty " published in Journal of Statistical Physics, 1992. I believe that that is the most influential and best scientific paper Shelly wrote until today and I am very grateful that I could take part in that endeavor. Succinctly: The statistical mechanics of Bohmian mechanics yields the Quantum formalism and Quantum Principles! All puzzles are resolved, all paradoxes have evaporated.

6 What is and to which end does one study physics ?

Physics is the science which aims at understanding how the exterior world functions. Thus physics is about ontology. The founding fathers Bohr and Heisenberg were wrong and were proven wrong in dogmatizing the impossibility of an ontological quantum theory of nature. Bohmian mechanics is a counterexample but there is more: There is GRW theory, a theory as sane as Bohmian mechanics but different from it in several respects: The wave function collapse is in Bohmian mechanics an effective means of description and good for practical purposes while it really happens in GRW theory. GRW stands for Ghirardi-Rimini-Weber. These theories without observers spell out what they are about, nothing is left to idle talk. To see how our world as we perceive it emerges from the theory, mathematical physics work needs to be done. Work well worth the effort.

The future problem which needs hard work is to release the tension between relativity and non-locality of nature. This is a formidable task which has been attacked by the new generation and the biggest success has been achieved in the GRW-flashes theory by Roderich Tumulka, now a colleague of Sheldon Goldstein at Rutgers.

For a long time it seemed that Einstein and Schrödinger had lost the battle for an ontological quantum theory, but the assessment of the situation has changed. It changed because of the work of distinguished physicists like Bohm, Bell, Ghirardi and Goldstein.

To end let me quote from Sir Michael Atiyahs Einstein Lecture[10]: " String theory, from this point of view, is only our method of approximating a simple reality. Perhaps, Atiyah suggested, we should follow Einstein and question quantum mechanics...Do we need to modify quantum mechanics? Atiyah closed by saying " This is for young people: Go away and explore it. If it works, dont forget I suggested it. If it doesnt, dont hold me responsible. " "

From the report of his lecture I cannot conclude whether Sir Michael Atiyah understood what Einstein's point concerning Quantum mechanics is, and what exactly it is that one should question about quantum mechanics.

But it brings me back to the question and to the scientific performance of the physicist Sheldon Goldstein.

To which end do we study physics?

One answer given by Schrödinger in his book *Science and Humanism* is: To understand who we are. I believe that any serious answer lies at least in the vicinity of Schrödinger's answer. What the answer implies is very much how I see and understand Shelly's scientific performance: The issue " Who understands what " is irrelevant! The relevant question is: " What new insight has been achieved? What new understanding do we have of Nature? How do we say it right? " And to the young generation he would say: " Clearly Einstein was right, quantum mechanics was incomplete. That is plain to see and it is the responsibility of every physicist to get clear about that. Go on from there. " And he would give them the warning, which we all, who had the pleasure to work with him, heard at least once from him. " But beware: Mathematics is easy, Physics is hard! "

[10]reported on in: The Nature of Space, G. W. Johnson and Mark E. Walker, NOTICES OF THE AMS, VOLUME 53, NUMBER 6, 2006