Caged in the quantum paradigm

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Is the typical view towards quantum mechanics, its "weirdness" and pressure to accept a specific *ignorabimus*, justified and necessary or rather an epistemological artifact perhaps preventing us from substantial progress? By separating the title into its three main constituents and following a constructivist and pragmatist line of thought arguments for the latter shall be collected.

1 Scientific Paradigms

What is shared between the disciples of a scientific community, structures and disciplines their way of thought, shall be called the *paradigm*. It consists of models, techniques and values formulated in a specific technical jargon as example, method or doctrine, written up in textbooks or passed down by lectures. The notion is commonly attributed to Thomas Kuhn and his magnum opus "The Structure of Scientific Revolutions" (1962) but has its predecessors already in the concept of a thought collective (Denkkollektiv) developed by Ludwik Fleck in the 1930s.[1] "Truth" therein is a relative value, having a meaning only within the group of people that adheres to a specific thought style (Denkstil). "Normal science" pursued by such a group tries to continuously enlarge its body of knowledge in the clichéd problem-solving, knowledge-gain style. Real progress, as Kuhn makes clear with numerous examples, is achieved through revolutions, so called "paradigm shifts", that shatter the old way of thinking and open the field for something new. Such a revolution does not occur with the first failure of an old paradigm like Popper's falsifiability criterion would suggest. Anomalies are usually met by adopting small adjustments or ad hoc explanations until a real crisis arises.

[1] Fleck, Ludwik (1935), *Entstehung und Entwicklung einer wissenschaftlichen Tatsache*

If a new paradigm is able to handle the crisis adequately it has the chance to rise to prominence, whereas the old theoretic building slowly crumbles and usually dies with its advocates.

Michel Foucault showed in a similar manner but in a broader sense that knowledge and its discourses within an epoch is culturally grounded in what he calls the *épistème*. It provides the "strategic apparatus which permits of separating out from among all the statements which are possible those that will be acceptable within [...] a field of scientificity, and which it is possible to say are true or false."[2]

Accounts in history of science like to portray the heroic rise of human knowledge as a "mirror of nature"[3] that pictures reality in the form of scientific theory, first blurry and vague but increasingly clear-cut and precise as tiles are added to the big puzzle. This is not only refused by the idea of radical paradigm change, when the puzzle is cleared away and completely new tiles arise, but also by the implausibility of such exact representations. Assuming an image of the world in our mind, there is no reason to believe it to be unique. For any collection of facts can be met with quite different and even incommensurable theories, and any counter-evidence to a theory can be met in different ways.

A very recent example is the detection of curls in the polarisation of the cosmic microwave background by the Harvard-Smithonian center for astrophysics. Because the currently held theory of gravity combined with a model for the Big Bang yields an explanation for such patterns it has been interpreted as the "first direct evidence"[4] for cosmic inflation *and* the existence of gravitational waves. One clearly sees the deviation from Aristotelian reasoning in such a conclusion but it can indeed be justified with what Charles Sanders Peirce first called "guessing" and what was later termed "abduction". Assume that if a holds then b would be a matter of course, so the observation of a surprising fact b indicates towards the hypothetical explanation a. Thus a is (nearly) sufficient but not necessary for b and indeed one could surely find other causes for curly patterns in the cosmic microwave

[2]Foucault, Michel (1980), *Power/Knowledge*, p. 197

[3]from the title of Rorty, Richard (1979), *Philosophy and the Mirror of Nature*

[4]`http://www.cfa.harvard.edu/news/2014-05`

background.

Peirce introduced pragmatism as the "logic of abduction". Its maxim is that the conception of effects is the whole of our conception of an object. From Ernst Mach's positivist-empiricist viewpoint the available data would always and only be such *as if* there is matter out there. This is part of the Duhem-Quine thesis of holistic theory building that there is no empirical test without certain fundamental assumptions relying to experimental set-up, evaluation of data and theoretical prejudice. Thus "the image of the scientist gradually unveiling the mysteries of a world that is and forever remains what it is, does not seem appropriate."[5] Because truth is a property of propositions made by humans, so are truths themselves man-made, parallel to the Protagorean claim that "Man is the measure of all things." Or as Heinz von Foerster put it: "Objectivity is the delusion that observations could be made without an observer."[6] Without the possibility of strictly corresponding truth, foundationalist epistemology is in vain as would be any quest for a final *Theory of Everything*. A complete picture of reality would be reality itself. This also undermines any given hierarchy in scientific theory, imagine a pyramid with Quantum Field Theory and General Relativity at its top, as each part is only a model for a specific domain of observed phenomena. This idea of the natural "imperialism of physics"[7] is refused as there is no generally valid reduction to first principles.

2 The Quantum Paradigm

Let's delve deeper into our own field of expertise and try to uncover what a coherent quantum paradigm could be. The historical starting points for quantum mechanics in the usual narrative are Planck's black-body radiation law, Einstein's explanation of the photoelectric effect and the Compton scattering effect followed by Bohr's account for chemical spectra. Then most old-school textbooks jump right away to the wave function and its wave equa-

[5]Glasersfeld, Ernst von (2001), *The Radical Constructivist View of Science* in Foundations of Science **6**

[6]quoted above

[7]Earman, John (1992), *Bayes or Bust*, quoted after Quale, Andreas (2008), *The Issue of Reductionism* in Constructivist Foundations **4**

tion (suggested by Debye, found by Schrödinger). Often they try to formulate quantum mechanics "axiomatically" following Dirac and von Neumann with something like (i) wave-function, (ii) observables, (iii) their expectation values, (iv) dynamics and (v) collapse. Add to this logico-mathematical framework a mélange of iconic thought/real experiments and the trouble starts.

The first one is the double slit experiment, which by Feynman's account "[...] has in it the heart of quantum mechanics. In reality, it contains the only mystery [of quantum mechanics]."[8] As early as 1927 it ignited the now-famous debate between Bohr and Einstein and led to the ever continuing interpretational quarrel.[9] The result on one side was an approach dubbed the Copenhagen interpretation by Heisenberg with complementarity and a reference to an outer classical world opposed to the quantum realm at its core.

This duality of worlds is already embedded in the quantum formalism if one imagines the theory valid for a universe consisting of an investigating consciousness, the notorious observer, and everything else as the system, both with well defined quantum numbers o and s. Thus the common state is $|o, s\rangle$ which could eventually evolve into a superposition $c_1|o_1, s_1\rangle + c_2|o_2, s_2\rangle$. As soon as one can clearly discriminate those states of mind, i.e. $\langle o_1|o_2\rangle = 0$, it is compulsory to single out the alternative *that is the case* and the universe collapses to $|o_1, s_1\rangle$ or $|o_2, s_2\rangle$ respectively. But a continuity of consciousness implies knowledge about my state of mind at every instant of time which means such superpositions can never occur, thus leading to a natural cut between the observer and the observed. This Heisenberg cut between the classical and the quantum from the Copenhagen interpretation is now just the Cartesian cut between the *res cogitans* (thinking substance) and *res extensa* (extended substance). To guarantee the assumed continuity of consciousness we might draw the cut back to the pure essence of being, the personal identity, a primitive *cogito*. In this way such a cut arises naturally and a quantum state $|s\rangle$ must be taken as purely subjective and constructed.

[8] Feynman, Richard P. et al. (1964), *The Feynman Lectures on Physics, III.*

[9] see Wheeler, John A. and Zurek, Wojciech H. (Eds., 1983), *Quantum Theory and Measurement* for a general account

The realist side in the Bohr-Einstein debate remained productive as well and in 1935 came up with the gedankenexperiment of the cat and the EPR paradox. The common theme was entanglement and Schrödinger highlighted its significance when saying: "I would not call that *one* but rather *the* characteristic trait of quantum mechanics, the one that enforces its entire departure from classical lines of thought."[10] In this sense it served as the main ingredient in the later development of quantum information theory and quantum computing.

Along this long and winding path of arguments a host of other interpretations sprung off, attributing reality to quite different parts of more or less the same theory that seems to allow such interpretational freedom as part of its paradigm. But these interpretations betray quantum mechanics of its constructivist foundation as reality becomes thinkable in many facets. This fits to the postmodern condition of Lyotard where the big story "is being dispersed in clouds of narrative language"[11] with a consecutive loss of a single truths legitimacy.

Still the image of great consistency of quantum mechanics is purported at least in most textbook accounts notwithstanding that even the three "coffin nails" for classical theory – black-body radiation, photoelectric effect and Compton scattering – can find proper semi-classical explanations by purely classical electromagnetism and wave mechanics which was not yet available at the times of their finding. Further there can be no saying of quantum mechanics really substituting classical mechanics as a world view or in practical applications. What remains of its central paradigm is essentially the property of "non-classicality", a severe deviation from the old ways of thinking.[12]

[10]Schrödinger, Erwin and Born, Max (1935) *Discussion of probability relations between separated systems*, Mathematical Proceedings of the Cambridge Philosophical Society **31**

[11]Lyotard, Jean-François (1979) *The Postmodern Condition: A Report on Knowledge*

[12]Compare the interesting thesis of Paul Forman, *Weimar Culture, Causality, and Quantum Theory, 1918-1927* (1971), that the early development of quantum theory was at least in parts an adaption to a cultural environment during the Weimar period hostile to the classical natural sciences. The willingness to part with causality and even rationality was then already manifest in the scientific community.

3 The Cage

The idea of the cage starts with a sentiment of irrationality. That is not the anti-realist approach towards knowledge about the world but an embracement of the accused strangeness of a real quantum universe out there. We hear statements like: "The weirdness of the quantum world is real, whether we like it or not."[13] Others argue for irrationality from first principles: "My personal feeling is that we have found for the first time in physics that there are things which happen without sufficient reason. This, I think, is a very profound discovery. I don't know whether there is a way to understand this or not. I feel there might be a way to understand why the world is so strange but we have not understood that yet."[14] Or like a popular undergraduate textbook puts it: "[...] the conceptual difficulties which are inherent in the quantum mechanical state do not imply a weakness of quantum theory, whose validity has never encountered limitations, but only a weakness of our imagination."[15] Which somehow suggests that the human mind cannot grasp an idea conceived by itself. Kant formulated the reverse as a precondition "that reason can comprehend only what she herself has brought forth according to her design."[16] Wordings as above are very apt to discourage any devoted student and the principality of the cannot-know acts as a comforting pacifier towards the insufficiencies within the theory.

Such a viewpoint is to be criticised especially against the background of quantum theory fulfilling the everyday role of the most advanced and successful scientific theory. In this popular role it increasingly dictates to a huge extend the ways other research steers. This influence stretches from closer terrains like high energy physics, condensed matter physics and cosmology out into the far regions of cognitive science. But only a very small and rather indefinite core of a quantum paradigm is really shared between all those quite different domains of human knowledge and the hazard of "quantum quack-

[13] Tegmark, Max and Wheeler, John A. (2001), *100 Years of Quantum Mysteries*, Scientific American

[14] Zeilinger, Anton (1994) at the Symposium on the Foundations of Modern Physics in Helsinki, quoted after Christopher A. Fuchs

[15] Schwabl, Franz (2007), *Quantum Mechanics* (4th ed.), p. 371

[16] Kant, Immanuel (1787), *Critique of Pure Reason*

ery" such as quantum healing persists.

So is the relative freedom of interpretations an effective distraction? Has the realm of classicality been left too early, as Feyerabend suggests,[17] and should we aim for a description of a perfect Parmenidian world augmented by explanations why it appears so different to our senses? When staying inside the realm of physics it is a democracy of methods that should be maintained where radical conceptions have a place to evolve and gain ground. It is a methodological pluralism directed against the hegemony of a single paradigm. It is thinking outside the "cage".

[17]Feyerabend, Paul (1979), *In Defence of Classical Physics*, Hist. Phil. Sci. **1**