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Robert Nadeau and Menas Kafatos, *The Non-Local Universe. The New Physics and Matters of the Mind.* Oxford: Oxford University Press, 2001, xvi+240 pages. ISBN 0–19–514408–2 (Pbk.)

Reviewed by Ricardo Parellada (Universidad Europea de Madrid)

1. Non-locality and complementarity*

The main thesis of this book is that quantum non-locality calls for a completely new understanding of the relation between mind and world. Non-locality is the property of quantum systems which show correlations between parts with both a common origin and an actual space-like separation. According to Nadeau and Kafatos, this extraordinary physical fact should help us to understand the emergent properties of organic molecules, cells, and organisms, that cannot be explained in terms of the sum of the parts. Moreover, quantum non-locality should also account for the emergence of mind and consciousness out of the physiology of the brain, and even for ascribing mental properties to the universe as a whole.

Although they are not explicit in the Table of Contents, the proposals of this book fall in three quite different parts. First, after mapping their journey in the introduction and chapter one, the authors present in chapters two to four a short history of modern physics from relativity theory to the Aspect and Gisin experiments demonstrating non-locality. Second, they apply in chapters five to seven the quantum notions of non-locality and complementarity to biology and anthropology, from DNA and microbial life to symbol-making and consciousness. Third, they devote chapters eight to ten to mind matters, as they say, showing the connections of the new physics with philosophical postmodernism, the prison house of language, eastern metaphysics, economic theory, and the ecological paradigm. They finally cry out for peace in the two-culture war between humanists and scientists in the name of quantum non-locality.

Nadeau and Kafatos begin their story of modern physics with the

Michelson/Morley experiment and the black body problem, and then provide a clear synthesis. The outcome of the Michelson/Morley experiment, the constancy of the speed of light, and the invariance of physical laws in inertial systems, are the basis of Einstein's special relativity, whereas the quantum hypothesis was put forward by Planck in order to account for the unexpected black body radiation distribution. After mentioning the central ideas in general relativity theory, the authors review the crucial moments in the development of quantum physics: photoelectric effect, energy levels and atomic structure, wave-particle duality, two-slit experiment, probability distribution, superposition principle, collapse of the wave function, and indeterminacy principle.

Chapter four is dedicated to non-locality. In 1935 Einstein, Podolsky and Rosen published an influential paper with a thought experiment intended to show the incompleteness of quantum theory. The spin of a pair of photons simultaneously created, for example, is conserved no matter how far away they should end up. Now, according to the theory, the spin of a single photon is determined only when measured, which entails the determination of the spin of the other photon, even if both events are separated by a space-like distance, that is, a distance that cannot be covered at light speed. Einstein, Podolsky and Rosen (EPR) argued that the spin of the second photon must have been determined from the outset and that the quantum-mechanical description should be regarded as incomplete, because no conception of reality could be compatible with such instantaneous correlations or entanglement, i.e., with quantum non-locality.

In 1964 John Bell proved that under the EPR assumptions certain inequalities hold between the outcome of the different spin projections of the photons that would be violated according to quantum theory and that, if the spin projections were determined as EPR suggested, the inequalities would not hold. Bell's paper proves that, if the inequalities are violated, there are no hidden variables that determine spin before decorrelation occurs.

After several attempts were made, Alain Aspect and his team were able to set up an experiment with polarised photons in 1982 which showed almost conclusively that the inequalities were violated, and therefore that correlations exist, and there is no basis for regarding quantum description as incomplete, as EPR tried to do. Aspect tested correlations between photons which went through polarisers that switched orientations every 10 nanoseconds and were thirteen meters apart, when information travelling at light speed would have needed 40 nanoseconds to connect them. Nicolus Gisin and his colleagues provided evidence in 1997 that correlations between paired photons did not

diminish with distance, putting up a device that showed them when they were eleven kilometres apart, a huge distance in the quantum scale.

Quantum non-locality is presently regarded, according to Nadeau and Kafatos, as an established property of nature, and has remarkable implications:

> All particles in the history of the cosmos have interacted with other particles in the manner revealed by the Aspect experiments. Virtually everything in our immediate physical environment is made up of quanta that have been interacting with other quanta in this manner from the big bang to the present. Even the atoms in our bodies are made up of particles that were once in close proximity to the cosmic fireball, and other particles that interacted at that time in a single quantum state can be found in the most distant star… Thus non-locality, or non-separability, in these experiments, could translate into the much grander notion of non-locality, or non-separability, as the factual condition in the entire universe (p. 81).

Quantum non-local correlations are inconceivable within the classical frame of mind, that is, viewing photons simply as distinct particles with a common origin. On the contrary, the whole situation must be considered as a single non-analysable quantum state, in which wave and particle manifestations are complementary aspects of reality. Complementarity is the key notion that accounts for the fact that quantum entities cannot be considered waves or particles before the act of measurement. When these entities interact with the experimental apparatus, they manifest as one or the other, but quantum theory rules out the possibility of ascribing them a previous definite nature. One way to assign photons definite properties before measurement was proposed in the EPR thought experiment, but Bell showed it led to predictions opposite to those of quantum theory, and the Aspect and Gisin experiments have proved the latter to be right. The quantum notion of complementarity can also be applied to physical magnitudes whose simultaneous determination is restricted by the indeterminacy principle, such as position and momentum or time and energy, which are represented by non-commuting operators.

2. Emergent properties and mind matters

Nadeau and Kafatos argue very imprecisely that the use of the notion of complementarity can be extended beyond the restricted domain of quantum physics. In general relativity, space and time are revealed as "profound complementarities that exist within the larger whole of the space-time continu-

um" (p. 101). In mathematics, real and complex numbers, differential and integral calculus, and even zero and infinity, are equally fundamental and pervasive complementarities: "Although the fullness of infinity is logically antithetical to the emptiness of zero, infinity can be obtained from zero with a simple mathematical operation. The division of any number by zero is infinity, while the multiplication of any number by zero is zero" (p. 102). Moreover, complementarity should also be regarded as the authentic "logic of nature" in biological reality, for it provides the basis for understanding the progressive emergence of wholes "that display properties and behaviour that cannot be explained in terms of the sum of the parts" (p. 103).

As the authors say, at the most basic level quanta interact with other quanta in and between fields to produce the roughly one hundred elements that display emergent properties that do not exist in the particles themselves. The elements combine to form compounds and minerals that display emergent properties not present in the elements themselves. The parts associated with compounds and minerals combined to form a new whole in the ancestor of DNA that displays emergent properties associated with life. During evolution, the exchange of parts of DNA between prokaryotes as well as mutations displayed new emergent properties, and resulted in new wholes in eukaryotes that display emergent properties not present in prokaryotes. The mind displays consciousness as an emergent capability from the physiology of the brain. And the biota as a whole exhibits too emergent properties not present in individual organisms.

"Obviously", claim Nadeau and Kafatos, "what we are saying here about the relation between part and whole in biological life is analogous to what we have said about the part-whole complementarity disclosed by nonlocality" (p. 120). And a few lines later they make their point in the following terms:

> In the absence, however, of any understanding of mechanisms linking quantum mechanical processes and progressive emergent behaviour in biological life, the only valid conclusion is that the logic of complementarity can serve as a heuristic for understanding fundamental part-whole complementarities in both physical and biological realities (*ibid.*).

Now, in the absence of any understanding of mechanisms linking quantum mechanical processes and progressive emergent behaviour in biological life, it is far from obvious that the relation between part and whole in biological systems should admit any reasonable analogy with quantum non-locality and complementarity. It is true that all kinds of physical and biological wholes display properties that cannot be explained simply in terms of the sum of the

parts. Complex molecules, cells or organs cannot be understood considering only interactions between photons or elementary particles. We need chemical, biochemical and physiological laws and properties, and the term 'emergent properties' is nowadays widely used to point to this fact. But the authors of this book just repeat the term again and again, providing no insight into, or relevant commentary on, the emergence of any kind of properties. Even though they admit they can show no link between quantum and complex biological processes, at the same time they insist that non-locality and complementarity explain them all.

The back cover, the introduction and several other passages of the book promise a revolutionary look at the implications of quantum non-locality for the understanding of human consciousness. But there is nothing of the sort here. The only idea concerning the mind is that it displays emergent properties that cannot be accounted for by focusing on the physiological mechanisms of the brain:

> If we could, for example, define all of the neural mechanisms involved in generating a particular word symbol, this would reveal nothing about the actual experience of the word symbol as an idea in human consciousness. Conversely, the experience of the word symbol as an idea would reveal nothing about the neuronal processes involved. And while one mode of understanding the situation necessarily displaces the other, both are required to achieve a complete understanding of the situation (p. 143).

This way of acknowledging the specificity of mental or psychological phenomena is, in my opinion, a much better start in the philosophy of mind than comparing brain and mind with a thermostat and its achievements, which is not an unusual approach. But it is actually very little, and shows no connection with non-locality. In this book there is one passing mention of Penrose's questionable attempt to ground consciousness in a quantum mechanical process by privileging the collapse of the wave function, but it offers no analysis or commentary on it (p. 184).

According to Nadeau and Kafatos, the difficulties of connecting quantum matters and human consciousness diminish enormously when we contemplate the link between quantum non-locality and the consciousness of the universe as a whole:

> If the universe is a seamlessly interactive system that evolves to higher levels of complexity and if the lawful regularities of this universe are emergent properties of this system, we can assume that the cosmos is a single significant whole

> that evinces progressive order in complementary relation to its parts. Given that this whole exists in some sense within all parts (quanta), one can then argue that it operates in self-reflective fashion and is the ground for all emergent complexity. Since human consciousness evinces self-reflective awareness in the human brain and since this brain (like all physical phenomena) can be viewed as an emergent property of the whole, it is not unreasonable to conclude, in philosophical terms at least, that the universe is conscious (pp. 197–198).

I admit that I cannot grasp the logic of this "not unreasonable" way to conclude, nor see the point of the qualification "in philosophical terms at least".

Quantum correlations should have, therefore, proved wrong "the radical separation between mind and world sanctioned by classical physics and formalised by Descartes", which remains, "as philosophical postmodernism attests, one of the most pervasive features of Western intellectual life" (p. 148). The authors apply this clue to review in passing the postmodern contributions of Nietzsche, Husserl, Cantor, Saussure, Gödel, Lacan, Barthes, Foucault, and Derrida, as well as the main tenets of the prison house of language, Berger and Luckman's social construction of reality, eastern metaphysics, Adam Smith's invisible hand, Wilson's socio-biology, and Capra's ecological world view. As could be expected, the conclusion of all this nonsense is that time has come to make peace, in the name of quantum non-locality, in Snow's two-culture conflict, which has lately degenerated into the two-culture war:

> Let us, therefore, put an end to the absurd two-culture war and get on with the business of coordinating human knowledge with the interests of human survival in a new age of enlightenment that could be far more humane and much more enlightened than any that has gone before (p. 218).

Note

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