

On Macroscopic Intricate States

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Abstract

The present contribution is in the field of quantum modelling of macroscopic phenomena. The focus is on one enigmatic aspect of quantum physics, namely the Einstein-Podolsky-Rosen paradox and entanglement. After a review of the state of the art concerning macroscopic quantum effects and quantum interaction, this contribution proposes a link between embryology and acupuncture in the framework of macroscopic intricate states induced by quantum mechanics. Could a weak form of intrication be maintained during stem cell division in order to interpret the acupuncture meridians as an explicit manifestation of a macroscopic intricate system?

Keywords: fractaquantum hypothesis, Atom, acupuncture, embryology, stem cells.

Introduction

First recall the astonishing quantum phenomenon observed by Aspect and his colleagues (Aspect, Grangier, Roger, 1982): using calcium cascade source, a double photon is emitted in two opposite directions. From the quantum point of view, this double photon is a unique pure state, an entangled state, even if it is located in two different places. When a measure is done on one of the photons, the reduction of the wave packet operates instantaneously on both components. From a so-called classical realistic point of view, we are in presence of two objects interacting together whereas from the quantum point of view, we are in front of a unique entangled state that occupies two different macroscopic spatial positions during the Einstein-Podolsky-Rosen-Bohm experiment (Einstein, Podolsky and Rosen, 1935, Bohm, 1951). When a measure occurs, the so-called reduction of the wave packet of the quantum approach predicts that the entangled state remains unique and responds in a holistic manner even if it occupies two separate space positions! There is a natural problem with the confrontation of such a point of view with the Einsteinian realism and in particular the theory of relativity that claims that no interaction can proceed at a celerity superior to the one of the light.

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A detailed analysis of possible cross-correlations has been proposed by Bell (1964). As a result, the so-called Bell inequalities show that precise experiment is possible in order to test whereas the two components of the entangled state remains correlated or not when they occupy different space positions. The experiment of two entangled photons has been proposed and realized with a great success by Aspect. The result shows that quantum mechanics gives the good prediction; the Bell inequalities are not satisfied by the experiment, even if “in many other situations, the Bell inequalities are not violated” (Aspect, 2005). Consequently, the holistic vision of the entangled photons is now experimentally well established.

Nevertheless, a main difficulty of these micro-physics experiments is due to the so-called decoherence, modeled by Zurek (1982) and experimentally established by Haroche and his co-workers (Brune *et al.*, 1996). When interacting with the environment, mesoscopic quantum systems loose quickly their coherence properties.

In this contribution, we are interested in possible macroscopic entangled states. In a first section, we review the main facts concerning this subject, including quantum key distribution and the quantum computer. We develop in a second part the fractaquantum hypothesis, motivated by the remark that Nature is both fractal and quantum. The fractaquantum hypothesis express that the quantum approach is relevant for all the elements in Nature, whatever their size. With this fractaquantum framework, we explore the possibility of intricate states in biology. In particular a link between acupuncture and embryology in Section 3.

1) Macroscopic entangled states

First observe a distinction between “entangled states” and “intricate states” as in our title. The term “intrication” seems clear, referring to a process that leads to entanglement. Examples in the literature wants to reserve the term “intricate states” to “localised entanglement”, such as the intrication happening when a microscopic particle interacts with a measuring device, for instance when an alpha-particle enters a detector. In a strictly point of view, the photon pairs in the Aspect’s experiment constitute a macroscopic entangled state. But such phenomena are also associated to quantum computers, quantum key distribution and quantum interaction.

- Quantum computer

The possibility of development of a quantum computer has been suggested by Feynman (1982). A \pm bit is replaced by a qubit, mathematically a set of two complex numbers whose sum of square modulus is equal to one. From a physical point of view, a quantum computer is a true macroscopic structure at a mesoscopic level and we refer the reader to the book of Nielsen and Chuang (2000). A quantum computer uses physics to perform an infinite number of scalar operations per cycle. The Shor algorithm (Shor, 1994) establishes that a quantum computer can factorize any integer N with a very fast algorithm, with $O((\log N)^3)$ elementary operations. A first factorization ($15 = 3 \times 5$) was obtained quickly (Vandersypen *et al.*, 2001). The progress are thereafter relatively slow : factorization ($143 = 11 \times 13$) with a 4-qubits computer (Xu *et al.*, 2012). The first reprogrammable quantum computer is constructed by Debnath *et al.* (2016). Observe that the decoherence is a strong limitation

to the development of quantum computer. The work of Ofek *et al.* (2016) show the state of the art on the of quantum error correction.

- Quantum key distribution

The communication of private keys is a fundamental question in cryptography. An important breakthrough has been obtained in 1984 with the “BB84” protocol, by taking into account the non-commutation of operators with oblic polarizers (Bennett and Brassard, 1984). The research group of Gisin has applied this protocol under Lake Geneva (Muller *et al.*, 1996) and extended it some years later (Branciard *et al.*, 2005). It has been also implemented over 80 km of optical fibre by the group of Grangier (Jouguet *et al.*, 2013). The violation of Bell’s inequalities is also a security test of a cryptographic installation against a possible aggression. The Ekert protocol (Ekert, 1991) uses explicitly the violation of Bell’s inequalities with an entangled pairs of photons. It can be viewed as an industrialization of the Aspect experiment. In a recent contribution (Vazirani and Vidick, 2014), a proof of security of a slight variant of Ekert’s original entanglement-based protocol is presented.

- Quantum interaction

We give in this sub-section some decorrelated discoveries showing the important scientific activity in the field. A Sino-German team has teleported quantum information from one ensemble of atoms to another 150 metres away (Bao *et al.*, 2012). The classification of macroscopic quantum effects is difficult. Farrow and Vedral (2015) propose three not mutually exclusive classes defined by mass, with interference of macromolecules, spatio-temporal coherence, with superconducting qubits and number of particles, with *e.g.* self interference of single particles in complex molecules. An entanglement in large atomic ensemble (3000 atoms) *via* the interaction with a very weak laser pulse has been observed by a Americano-Serbian team (McConnell *et al.*, 2015). Quantum spin dynamics and entanglement with hundreds of trapped ions is related by the team of Bohnet (2016). The quantum brain model of Vitiello (Ricciardi and Umezawa, 1967, Del Giudice *et al.*, 1988, Vitiello, 1995) show an other example of macroscopic entangled state. The water inside our brain could be a macroscopic set of correlated matter. Much of our understanding of human thinking is based on probabilistic models. With a quantum calculus of probabilities, Busemeyer and Bruza (2012) show that a much better account of human thinking is possible than with traditional models. Khrennikov (1999) has proposed classical and quantum mechanics on information spaces to understand anomalous phenomena in cognition, psychology and sociology. A quantum-like interference effect in gene expression is studied in the work of Basieva *et al.* (2011). In their book, Haven and Khrennikov (2013) explain why quantum mechanics can be applied outside of physics and define quantum social science. The adaptation of the mathematical formalism of quantum information theory in the biological context is proposed in the book of Asano *et al.* (2015).

2) Fractaquantum hypothesis

The present fractaquantum idea considering macroscopic applications of quantum mechanics is in the same spirit than from previous authors like Heisenberg (1969) for pioneering ideas

concerning quantum extensions. We refer also to McFadden (2000) for biology or Stapp (1993) for mind and brain. Note also intensive development concerning violation of Bell inequalities at a macroscopic scale by Aerts et al (2000), and Conte et al (2008) among others. We first recall fundamental aspects of fractals, develop our point of view concerning Atoms and underline the quantum classification between matter and relations. Then the fractaquantum hypothesis introduces naturally macroscopic bosons. We discuss also an important point concerning indiscernability and suggest the notion of weak intrication.

- Fractals

The introduction by Mandelbrot (1975) of the fractal geometry has been coupled with a real trouble. The fundamental remark is as follows: if we suppose that “the big is analogous to the little”, we obtain of course the straight lines of elementary geometry but also geometrical shapes that are absolutely not straight lines, called fractal curves, as the popular Peano curve (1890), Von Koch snowflake (1906) or Sierpiński triangle (1915). A fractal curve has an infinite length and remains unchanged under very simple geometric transformations. These self-similar geometrical shapes are present in our natural environment with trees, clouds, ferns or cauliflowers among others. They are present also in our own body with the detailed structure occupied by the lungs. A partial piece of a tree is analogous to the entire tree and this fractal property is characteristic of the fact that “the big is analogous to the little”. Let’s bare in mind that there is no constraint, Nature offers a spatial self-similarity: the “big” is analogous to the “little”, even if the corresponding shapes take a complex appearance.

- Atoms

Following a vision that comes from the antic Greek culture (see e.g. Salem, 1997), in this contribution, an Atom is any natural element whose qualitative properties are modified at least in one subset if we divide it into two parts. Of course, the modern atoms of Perrin (1913) that are studied with the atomic physics are Atoms in our understanding. A fundamental particle, *id est*, an entity without any internal relations, is an Atom and the existence of spin as an intrinsic kinetic momentum does not imply a relation. In particular, all classical elementary particles of microphysics, proton, neutron, and electron, ... are Atoms. Stable structures in Nature such as molecules in the usual sense given in chemistry are also Atoms. If I divide a glass of water, say 80 times, I have no more water. The structure of the molecule is broken and I obtain something else. The qualitative properties of water have been strongly modified by the last division. Moreover, the notion of Atom is not reduced to the micro-scale and we consider here a living cell as an Atom, due to all the properties that are strongly modified or destroyed if it is cut into two parts. We extend the family of Atoms to highly organised living organisms, including mammals and human beings. At a superior scale, it is not clear for us that the entire social organisation of life and exchanges on Earth constitutes or not an Atom, as suggested by Lovelock and Margulis (1974).

- Matter and relations

The main issue due to quantum theory according to us is the separation between “matter” and “relations”. On the one hand, matter is composed with fermions (protons, electrons, etc.) that are indistinguishable and follow the statistics of Fermi-Dirac. On the other hand, the relations, *i.e.* the interactions between elements of matter, are composed by bosons, like

photons, that are the elementary components of light. The bosons are also indistinguishable and follow the statistics of Bose-Einstein. The indiscernability of identical quantum Atoms is a fundamental postulate of the theory that is in clear accordance with the experiments. In particular, it is not possible to distinguish between two electrons or between two photons. Moreover, the Fermi-Dirac statistics implies also the Pauli exclusion principle that claims that two analogous fermions cannot occupy the same position in space. Our comment about the Pauli exclusion principle is that “matter creates space, relations give it a structure”.

- Fractaquantum relations

The fractaquantum hypothesis (Dubois, 2002) expresses that the quantum framework is pertinent for all Atoms in Nature, whatever their size.

Once the fractaquantum hypothesis is taken into consideration, we can explore its consequences for simple associations and configurations. Let's bare in mind that the quantum association of two identical particles of spin equal to $1/2$ conducts to a boson of spin equal to zero. However, such a boson is a relation because it is a quantum Atom of integer spin. Therefore, the anti-symmetric association of two Atoms of matter naturally defines a new relation. A fractaquantum consequence of this microscopic property is the existence at our scale of a lot of temporal associations that are constructed and exist in order to express some relation, some communication, some exchange (Dubois, 2006). A fractaquantum intercessor is a structure composed by two Atoms plus a relation between them.

For more complex structures, we can consider set of n vertices (or fermions for our example, Atoms of matter) are in relation, interact through a given set of m binary links, edges between two vertices. For example, the fractaquantum intercessor of the previous paragraph corresponds to $n = 2$, $m = 1$. More complex picture can be considered and the use of graph theory is now classical: in the framework of chemistry (Eigen, 1971), biology (Atlan, 1979). For a fractaquantum intercessor there is no loop and this kind of structure can be simply topologically reduced to a simple vertex (Berge, 1969).

- Discussion

In front of these ideas and strong assumptions, several objections and open questions can be formulated. A main drawback of the fractaquantum hypothesis is the contradiction of quantum indiscernability with macroscopic appearances. Concerning human beings for example, it is obvious that “we are all different”! One could conclude that the fractaquantum hypothesis is absurd and one could not consider it anymore. Our motivation to go one-step further is firstly motivated by classical philosophical observations introduced by Descartes (1641): “appearances are deceiving”. We take some time to develop some doubt.

If we refer to the human example, the common points between two human persons are much more important than the different ones. The existence of medicine establishes empirically this fact, as remarked by Nunez (2003). Moreover, the explicitation of genomic structure of deoxyribonucleic acid in each human cell (Venter *et al.*, 2001) show that two human deoxyribonucleic acid sequences coincide up to 1 for 10000 parts. Even if the single nucleotide polymorphism is widely studied in order to make in evidence local mutations (see *e.g.* Zhao *et al.*, 2003), the first established accounting fact from genomic studies is that two human

beings have the same sequence of deoxyribonucleic acid up to 99.99 %!

There exists also circumstances in quotidian life when two persons can be exchanged. With the example of a crowd, studied by Le Bon (1895) and Freud (1921), one can consider that a new entity is created, where each human being is reduced to a very primitive component and develop intense internal relations. In his contribution, Freud (1921) describes also social structures as religious organisations and army as artificial crowds! In such hierarchical organisation, each Atom is a priori exchangeable and is reduced to specific function.

As a conclusion of this discussion, the scale invariance in Nature is not an exact property. It is weakly broken due to discernability. Nevertheless, the fractaquantum hypothesis gives an interesting point of view to describe basic aspects of Atoms and Relations in Nature. It has to be considered as a starting point of a more precise theory. Moreover, we have developed the fractaquantum hypothesis in several fields like voting (Dubois, 2009, 2014), serendipity (Dubois, 2011), writing (2014), cognition (Lambert-Mogiliansky and Dubois, 2015), psychology (Lambert-Mogiliansky and Dubois, 2016) and meditation (Dubois and Miquel, 2015).

- A remark on individuation suggested by one referee

Social and biological systems recognise different individuals but fermions and bosons of the same species are completely interchangeable. This presents methodological problems. However, quantum modelling could also illustrate how individuation is achieved in social and biological systems. Is individuation a result of inherent properties or a result of interactions with the environment? A quantum system creates roles and the result of this process may come as a surprise to the scientific community. An example in point is the nuclear shell model. The nucleus was originally considered as a liquid-drop like system of protons and neutrons. That it actually arranged itself into shells with very clear roles for protons and neutrons came as a total surprise. In 1952, a major and very influential handbook on theoretical nuclear physics commented on the success of the shell theory for the atomic nucleus: “We are facing here one of the fundamental problems of nuclear structure which has not yet been solved” (Blatt and Weisskopf, 1952, p. 778). In a seminal paper, Gomes *et al.* (1957) solved the riddle and showed how the organisation into shells emerged from properties of the nuclear force. The surprises from the atomic nucleus illustrates how a quantum system of interchangeable elements self-organises into a structured system with very distinct eigenbehaviour.

- Weak intrication

A natural question is associated with the fractaquantum hypothesis: does entangled matter exist at a macroscopic scale? Is it possible to evidence at a macroscopic scale phenomena that show that two apparently distinct objects belong in fact to the same Atom? This question is highly difficult. The notion of intrication is well known at the microscopic scale. After an interaction of two systems during a given time interval, a new structure is created, even if it is located at several positions. For macroscopic Atoms, there is no explicit evidence that a past interaction can induce a true entangled structure in the future. The effect of such entanglement is not necessarily dominant, as it is the case for the Aspect photons for

example. Nevertheless, the consequences of a past interaction could be permanent. In this contribution, we name “weak intrication” such remaining link inside a macroscopic Atom generated by two previous structures, or by one structure that divides itself. Two weakly intricate Atoms occupy two distinct positions and have the appearance of a complete independence. Nevertheless, they still have some characteristics of entanglement: the interaction with one part of the system can produce an immediate reaction in the other part, without any explicit communication. We develop in the next section the possibility to interpret acupuncture with weak intricate structures associated to embryology.

3) Acupuncture and embryology

With the help of the fractaquantum hypothesis, we propose to construct links between embryology and acupuncture. We have suggested at the Afscet-Andé’s meeting (Dubois, 2006, 2014) that relations between acupuncture points and internal organs could be the sign of the existence of macroscopic intricate state. The correlation with the embryologic development could be a possibility to evidence the past interaction between the corresponding cells. We first recall fundamentals facts about acupuncture, then develop the question of embryology. Finally, we study possible relations between cell division and intrication.

- Acupuncture

Empirical knowledge developed in China since 3000 years with the acupuncture. A 2000 years old classical book is named “Nei Jing Su Wen” or “Huangdi Neijing” (Inner Classic of the Yellow Emperor), attributed to the mythical emperor Huang Di. Remember that acupuncture sets up some relations between the internal organs inside the body and some precise locations on the skin that are acupuncture points. Of course, these correlations resist to simple explanations through classical scientific approaches, even if recent contributions of Pariente *et al.* (2005) and Nedergaard *et al.* (Goldmann, 2010) create interesting links between modern scientific protocols and traditional acupuncture. Our hypothesis (2006, 2014), is the following: the meridians of Acupuncture follow families of intricate cells. There is no present link between these parts of the body. The link has to be founded in the past of the corresponding cells, in the embryologic development.

- Embryology

A single cell develops in a time that can be considered as short or long depending on point of view, in order to create a complex highly organized living being. The interaction with the environment is crucial and the way some global information could be presented at the final state of embryonic evolution is an open question that seems to be an acceptable possibility. It is very interesting in our quest to review the possibilities of inter-changeability of two cells during the embryogenesis. As we all know (see *e.g.* the book of Gilbert, 2006), a complex organism such as a human being comes from a single cell that divides many times and particularizes themselves. At a certain step of embryogenic development, all the embryonic stem cells (Evans and Kaufman, 1981, Martin, 1981) are identical and are a priori interchangeable. After a certain time, they are different, they look different and most important, they have been specialized in specific functions in order to promote the development of the entire

Atom to the superior scale. The understanding of the exact dynamics during the embryogenesis still is an open question. Moreover, we consider here that ethical reasons naturally limit the field of scientific research. We can also consider this fact as a macroscopic version of the Heisenberg inequalities. Following Heisenberg himself (1969), “we cannot make any observation without disturbing the phenomenon under observation”.

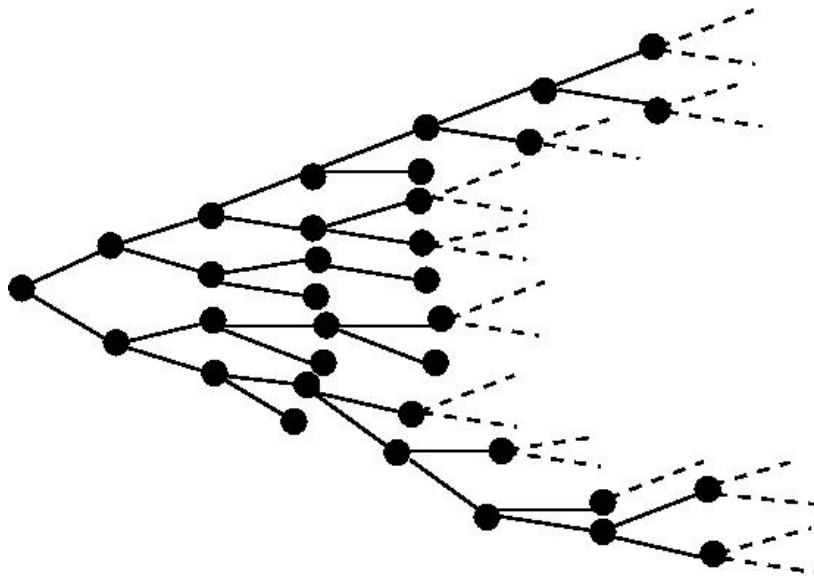


Figure 1. Time graph of the daughter cells from a single independent zygote. Time is going from left to right. A filiation structure is organized from a single zygote (left) to a complex tree.

- Cell division and intrication

The first question concerns cell division. Could this biological process create a macroscopic entangled state? This problem is not considered with this formulation by biological research teams. According to Hatfield *et al.* (2005), stem cell division is regulated by the micro ribosomal ribonucleic acid pathway. According to Bedzhov and Zernicka-Goetz (2014), self-organizing properties of mouse pluripotent cells initiate morphogenesis upon implantation. Nevertheless, according to O’Reilly and Olaya-Castro (2014) or Kourilsky (2016), quantum phenomena have to be considered in biology.

We place ourselves in a competitive paradigm between on the one hand the final unit (quantum holism) and secondly decoherence due to the interaction with the environment (“two cells”). Probably an efficient model of weak intrication could be intermediate between these two views. In this case, one can imagine that during cell division which is the primitive organism, especially during the first cell divisions of the blastocyst, a form of global unity, type entanglement, remains persistent.

In Figure 1, we stylized the embryonic process as a binary planar graph. It was of course a complex dynamic between the two cells “daughters” of the same original cell. This representation provides a hierarchical breakdown of the body’s cells. Indeed, a given cell of the human body is ultimately obtained at the end of cell division which has not subsequently followed by a new division. Thus the cells in a way a generation number. We formulated the

hypothesis that in some sense, the daughter cells remain connected. They form a structure of a tree, in the sens of graph theory. Moreover, this tree is an intricate macroscopic state. This structure should be naturally universal since embryo development is the same for all human beings.

Understanding cell division is a kea point concerning the possibility of intrication. In this case, there is not a single Atom composed by two components, as in the Einstein-Podolsky-Rosen-Bohm experiment. At the contrary, a single cell $|+\rangle$ interacts with its environment and generates a double cell that we can note as $|++\rangle$. This biological process is absolutly non trivial and we refer to the works of Croce and Calin (2005) and Bedzhov and Zernicka-Goetz (2014). From a mathematical point of view, quantum field theory has to be introduced since the total mass of the refering element (one single cell that becomes two cells) is changed. Probably, the co-product of Hopf algebras (see e.g. Cartier, 2006) is a good mathematical tool to describe the process of cell-division $|+\rangle \longrightarrow |++\rangle$.

Conclusion

With the framework of the fractaquantum hypothesis, we have considered the possibility of interpreting the acupuncture meridians as intricate cells since the early embryologic development. What is essential for our purpose, the links between the related components of an intricate macroscopic state are not explicit through space structure at a given time. It has to be founded in the time process of creating the cells. This explains why the meridians are not visible. A fundamental question is still open: during the division of a stem cell, can some weak form of intrication be maintained?

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