Workshop on Entanglement

November 28-29 2014
University Paris-Diderot
Room Luc Valentin, 454A*

Initially, the concept of entanglement has been coined by Schrödinger to describe a fundamental property of a composed, physical system whose parts have interacted in their common past (Schrödinger, 1935):

> "When two systems, of which we know the states by their respective representatives, enter into temporary physical interaction due to known forces between them, and when after a time of mutual influence the systems separate again, then they can no longer be described in the same way as before, viz. by endowing each of them with a representative of its own. 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. By the interaction the two representatives [the quantum states] have become entangled."

Entanglement is the central concept of quantum mechanics, which can explain non-locality phenomena, as in all EPR-like experiments. Entanglement can even be used as a physical resource in information protocols, like quantum cryptography or quantum teleportation.

Moreover, as recently suggested by some researchers, the concept of entanglement can be represented within the framework of a generalized, possibly weakened, version of quantum theory where all a priori references to the physical world have been relaxed –which thus gives rise to applications beyond the strict material domain.

This workshop aims to deal with the concept of entanglement according to its different aspects and its possible interpretations. Historical, physical, metaphysical, informational and generalized approaches to this very fruitful concept will be addressed.

PARTICIPANTS

Alexander **Afriat** (Université de Bretagne Occidentale),
Roberto **Angeloni** (BMC, SPHERE),
Harald **Atmanspacher** (Collegium Helveticum, ETH Zurich / IGPP Freiburg),
Guido **Bacciagaluppi** (University of Aberdeen),
Michael **Esfeld** (University of Lausanne), Thomas **Filk** (University of Freiburg),
Alexei **Grinbaum** (CEA-Saclay, SPEC/LARSIM),
Hartman **Römer** (Freiburg University), Pierre **Uzan** (SPHERE),
Harald **Walach** (European University Viadrina, Frankfurt (Oder))

ORGANIZATION OF THE WORKSHOP

Pierre **Uzan** (SPHERE), Gabriel **Catren** (CNRS, projet ERC Philosophie de la Gravitation Quantique Canonique) and Roberto **Angeloni** (BMC, SPHERE)

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To the Programme: Friday 28, Saturday 29
To the Abstracts
To the Practical Informations

FRIDAY NOVEMBER 28, 2014

9:00 — Pierre **Uzan** (SPHERE)
Presentation of the Workshop

Chair: Olivier **Darrigol** (SPHERE)

9:10 — Guido **Bacciagaluppi** (University of Aberdeen)
Did Bohr Understand EPR?

10:10 — Roberto **Angeloni** (BMC, SPHERE)
The holistic feature of the phenomenon of entanglement.

11:10 — Coffee Break

11:40 — Michael **Esfeld** (University of Lausanne)
Quantum entanglement and the primitive ontology of quantum physics.

12:40 — Lunch Break

Chair: Guido **Bacciagaluppi**

14:00 — Alexander **Afriat** (Université de Bretagne Occidentale)
Is the world made of loops?

15:00 — Alexei **Grinbaum** (CEA-Saclay, SPEC/LARSIM)
Reconstructing the Tsirelson bound.

16:00 — Coffee Break

Chair: Thomas **Filk**

16:30 — Harald **Atmanspacher** (Collegium Helveticum, ETH Zurich / IGPP Freiburg, Germany)
Epistemic Entanglement.

17:30–18:30 — Hartman **Römer** (Freiburg University, Germany)
Generalised Entanglement: Theory and Applications.

SATURDAY NOVEMBER 29, 2014 (restricted access to the building on Saturdays. Thanks for contacting P. Uzan)

Chair: Harald **Atmanspacher**

9:00 — Thomas **Filk** (University of Freiburg, Germany)
Forms and Signatures of Generalized Entanglement.

10:00 — Pierre **Uzan** (SPHERE)
Psychophysical Correlations as Relations of Generalized Entanglement.

11:00 — Coffee Break

11:30 — Harald **Walach** (European University Viadrina, Frankfurt (Oder), Germany)
Generalised Non-Locality – Solving Some Riddles and Opening New Avenues.

12:30–13:00 — Concluding Discussion.

ABSTRACTS
FRIDAY NOVEMBER 28, 2014

Guido **Bacciagaluppi** (University of Aberdeen), 9:10
Did Bohr Understand EPR?

Contrary to widespread belief, I argue that Niels Bohr's arguments in his reply to Einstein Podolsky and Rosen in 1935 take fully into account the separation between the two particles. Specifically, I argue that there is no sleight of hand in the passage from Bohr's discussion of a single particle passing through a slit and his subsequent discussion of the EPR example.

Roberto **Angeloni** (BMC, SPHERE), 10:10
The holistic feature of the phenomenon of entanglement.

The ambitious task to reconstruct Bohr's philosophy of physics on the basis of entanglement [Howard 1994] has been one of the most refined attempts to shed light on the philosophical foundations of the Copenhagen interpretation of quantum mechanics. It is evident that such an approach straightforwardly leads us to heed of the importance of the so-called doctrine of the classical concepts. In the wake of such an approach, I want to reconsider Bohr's key notion of "quantum postulate" as a fundamental premise of later mature interpretations of the phenomenon of entanglement. Specifically, Bohr stated: "the essence of the quantum theory is the quantum postulate", that is to say that the interaction between object and measuring agencies is conditioned by the very existence of the quantum of action [Bohr 1935]. Although Bohr's idea of the "quantum postulate" is nowadays considered as obsolete, his intuition (and of Heisenberg as well) that a measurement of a quantum-mechanical object triggers an "uncontrollable disturbance" of the latter is right [Landsman 2007].

It is worth remarking that there are holistic features also in Schrödinger's physics, whose origins are traceable back to statistical mechanics.

This presentation aims at comparing Bohr's, Schrödinger's, and Einstein's attitudes with respect to holism and separability. The concept of wholeness will be the term of comparison among the above approaches to quantum mechanics for better explaining such different standpoints with regard to the phenomenon of entanglement.

Michael **Esfeld** (University of Lausanne), 11:40
Quantum entanglement and the primitive ontology of quantum physics.

The workshop argues for an understanding of quantum entanglement in terms of a dynamical structure that governs the temporal development of the distribution of matter in physical space (i.e. the primitive ontology of quantum physics). I show how we can achieve in this way an account of entanglement that makes quantum non-locality intelligible without falling into the pitfall of what Einstein dismissed as "spooky action at a distance".

Alexander **Afriat** (Université de Bretagne Occidentale), 14:00
Is the world made of loops?

Two of the (three or four) standard interpretations of the Aharonov-Bohm effect involve 'entanglements,' of different kinds. Among other things I discuss Richard Healey's 'holonomy' interpretation, in which certain fundamental properties are possessed not by points but (holistically) by much larger regions.

Alexei **Grinbaum** (CEA-Saclay, SPEC/LARSIM), 15:00
Reconstructing the Tsirelson bound.

The amount of correlations allowed by quantum entanglement corresponds to the Tsirelson bound of Bell inequalities. I'll discuss the meaning of this bound and several possible ways to derive it.

Harald **Atmanspacher** (Collegium Helveticum, ETH Zurich / IGPP Freiburg, Germany), 16:30
Epistemic Entanglement.

Quantum entanglement relies on the fact that pure quantum states are dispersive and often inseparable. Since pure classical states are dispersion-free they are always separable and cannot be entangled. However, entanglement is possible for epistemic states (distributions) of classical dynamical systems. The crucial condition for such epistemic entanglement is that the phase space partition defining epistemic states is not generating. This result is relevant for any state-space represented system behavior with limited measurement accuracy, and it raises the problem of how to distinguish epistemic entanglement rigorously from genuine quantum entanglement.

Hartman **Roemer** (Freiburg University, Germany), 17:30–18:30
Generalised Entanglement: Theory and Applications.

Generalised Quantum Theory as developed by the speaker together with H.Atmanspacher and H.Walach is a minimal formal framework in which quantum theoretical notions like complementarity and entanglement can still be defined. Stepwise enrichment up to the full formalism of quantum physics remains possible. We shall discuss the definition of entanglement within Generalised Quantum Theory and give some Examples of possible applications going beyond ordinary quantum physics.

SATURDAY NOVEMBER 29, 2014

Thomas **Filk** (University of Freiburg, Germany), 9:00
Forms and Signatures of Generalized Entanglement.

In traditional (standard) quantum theory, entanglement has a precise mathematical meaning, and even though measures for and degrees of entanglement are still a subject of research, it is clear how entanglement reveals itself in experiments. However, there are many generalizations of the quantum formalism and, therefore, also many possible generalizations of the concept of entanglement. I will discuss and compare some of these generalizations, with particular emphasis on the options and constraints for empirical tests.

Pierre **Uzan** (SPHERE), 10:00
Psychophysical Correlations as Relations of Generalized Entanglement.

Logical difficulties seem to appear if we try to maintain at the same time that 1) mental states are distinct from physical (or neurophysiological) states, 2) mental states have a causal efficacy, and 3) a materialist position, which leads us to assert the causal closure of the material domain and the supervenience of the mental on the physical. Most of the neuroscientists and the philosophers presently uphold a materialist-reductionist position according to which mental states would, in some way, be "reducible" to their neurophysiological correlates, facing then the difficult question of explaining why and how we can have subjective experience.

I will argue that it is indeed possible to maintain the non-reducibility of the mental to the physical provided that the psychophysical correlations are understood in terms of relations of generalized entanglement –and not in terms of efficient causality. This quantum-like position, which takes its philosophical roots in Spinoza's and Leibniz' psychophysical parallelism, considers the individual as an only system whose states are entangled in their "natural" basis of description (that is, in the basis determined by the usual, somatic and mental properties we can measure). This approach can be applied to deal with phenomena that cannot be fully understood according to a classical mode of thinking, like the placebo effect or the appearance and the development of diseases.

Harald **Walach** (European University Viadrina, Frankfurt (Oder), Germany), 11:30
Generalised Non-Locality – Solving Some Riddles and Opening New Avenues.

A generalised type of non-locality is predicted by Generalised Quantum Theory (GQT) as a form of interrelatedness between various elements of systems under clearly defined preconditions. The program of generalising quantum theory hinges on the answer to the question, whether handling incompatible operations

or variables can be meaningful also outside the realm of quantum physics proper. At face validity this seems to be the case. For the minimal requirement is the fact that a measurement changes the state of the measured variable, and hence the sequence of operations is relevant. There are many examples from psychology, or our lived world, where this is likely the case. Hence it is also a reasonable assumption that the non-locality derived from this situation might be much more widely relevant than hitherto thought.
In this presentation I will give an outline of practical examples and of the explanatory potential of generalised non-locality, as well as some cautionary notes. Experimental results of a recent experiment we did seem to point towards the direction of experimental validation. If accepted, we might have a principle of systematic relationships between systemic elements of various systems of different kinds and sizes, that might complement classical, signal and interaction dependent causal interrelations.
This could be understood as a coordinating principle that helps optimise coordination within systems and thus delineating borders between systems. It can be used to understand such different phenomena as non-local interactions between minds, or mental and material systems, or transference experiences in relationships, or macro-trends in society, as well as the use of ritual and biological phenomena.

Practical Informations

Registration is free. However, for a question of practical organisation and also of security (ACCESS to the building on Saturdays) please email : pierre.uzan@paris7.jussieu.fr

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Access map.

Metro: Line 14 and RER C, stop: Bibliothèque François Mitterrand or line 6, stop: Quai de la gare.
Buses: 62 and 89 (stop: Bibliothèque François Mitterrand), 325 (stop: Watt),
64 (stop: Tolbiac-Bibliothèque François Mitterrand)

Website of SPHERE: http://www.sphere.univ-paris-diderot.fr

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