Frontiers of Fundamental Physics 14
List of speakers in conference
Epistemology and Philosophy

Updated on January 8, 2015

Alexander **Afriat** (UBO) **July, 15, 17h00 – 17h35, Room 408, Epistemology and Philosophy**

Weyl's gauge argument

The standard $U(1)$ "gauge principle" or "gauge argument" produces an exact potential $A = d\lambda$ and a vanishing field $F = d^2\lambda$. Weyl [1,2] has his own gauge argument, which is sketchy, archaic and hard to follow; but at least it produces a curved potential A and nonvanishing field $F = dA$. I attempt a reconstruction.

References
[1] Weyl, H. (1929) "Elektron und Gravitation" *Zeitschrift fuer Physik* **56**, 330-52
[2] Weyl, H.(1929) "Gravitation and the electron" *The Rice Institute Pamphlet* **16**, 280-95

Eric **Audureau** (CEPERC) **July, 18, 15h40 – 16h15, Room 408, Epistemology and Philosophy**

Kurt Gödel's theory of gravitation

Gödel's contribution to GR [1] have been criticized by several first rank physicists like Chandrasekhar, R.Ellis, S.Hawking, R.Penrose, J.Wheeler [2]. These criticisms (lack of physical meaning, violation of causality,...) contrast with Gödel own description of his work: "[It] relates to the pure theory of gravitation published in 1916 which, I believe, was left, not only by Einstein himself but also by the whole generation of contemporary physicists, in its state of a torso, physically, mathematically, and with respect to its application in cosmology." I will, in first place, explain why reccurent crticisms addressed to Gödel's exact solutions of Einstein's field equations are unjustified. In second place, I will illustrate in what sense Gödel's contributions to GR is what Einstein tried to do in 1917, namely a completion of the theory of gravitation.

References
[1] Kurt Gödel, Collected Works, Volumes I-V, ed. S. Feferman et al., Oxford University Press, 1996-2004.
[2] C.W. Misner, K.S.Thorne, J.A.Wheeler, Gravitation, W.H.Freeman & Co, 1973.

Paolo **Bertozzini** (Thammasat Univ.) **July, 17, 15h40 – 16h15, Room 408, Epistemology and Philosophy**

Categorical Operator Algebraic Foundations of Relational Quantum Theory

We provide an algebraic formulation of C.Rovelli's relational quantum theory [1] that is based on suitable notions of "non-commutative" higher operator categories, originally developed in the study of categorical non-commutative geometry [2,3,4].

As a way to implement C.Rovelli's original intuition on the relational origin of space-time [5], in the context of our proposed algebraic approach to quantum gravity via Tomita-Takesaki modular theory [6], we tentatively suggest to use this categorical formalism in order to spectrally reconstruct non-commutative relational space-time geometries from categories of correlation bimodules between operator algebras of observables.

References
[1] C. Rovelli, *Relational Quantum Mechanics*, Int. J. Theor. Phys. 35 (1996) 1637 [arXiv:quant-ph/9609002]
[2] P. Bertozzini, R. Conti, W. Lewkeeratiyutkul, *Non-commutative Geometry, Categories and Quantum Physics*, [arXiv:0801.2826v2].
[3] P. Bertozzini, R. Conti, W. Lewkeeratiyutkul, *Categorical Non-commutative Geometry*, J. Phys.: Conf. Ser. 346 (2012) 012003.
[4] P. Bertozzini, R. Conti, W. Lewkeeratiyutkul, N. Suthichitranont, *Strict Higher C^*-categories*, preprint(s) to appear.
[5] C. Rovelli, *Half Way Through the Woods*, The Cosmos of Science, J. Earman, J. Norton (eds.), University of Pittsburgh Press (1997) 180-223.
[6] P. Bertozzini, R. Conti, W. Lewkeeratiyutkul, *Modular Theory, Non-commutative Geometry and Quantum Gravity*, SIGMA 6 (2010) 067[arXiv:1007.4094v2].

Gabriel **Catren** (SPHERE) **July, 15, 17h35 – 18h10, Room 408, Epistemology and Philosophy**

On the Relation Between Gauge and Phase Symmetries

We propose a group-theoretical interpretation of the fact that the transition from classical to quantum mechanics entails a reduction in the number of observables needed to define a physical state (e.g. from *q and p* to *q or p* in the simplest case). We argue that, in analogy to gauge theories, such a reduction results from the action of a symmetry group. To do so, we propose a philosophical-oriented analysis of formal tools coming from symplectic geometry and group representation theory, notably Souriau's *moment map*, the *Mardsen-Weinstein symplectic reduction*, the *symplectic "category"* introduced by Weinstein, and the conjecture (proposed by Guillemin and Sternberg) according to which "quantization commutes with reduction". By considering the case of an abelian Hamiltonian action on a symplectic manifold, we argue that *phase invariance in quantum mechanics and gauge invariance have a common geometric underpinning, namely the symplectic reduction formalism*. This stance points towards a gauge-theoretical interpretation of Heisenberg indeterminacy principle. We revisit (the extreme cases of) this principle in the light of the difference between the *set-theoretic points* of a phase space and its category-theoretic *symplectic points*.

References

[1] Abraham R., Marsden, J.E.: Foundations of Mechanics (2^{nd} edition). Addison-Wesley Publishing Company (1978).
[2] Bursztyn H., Weinstein, A.: Poisson geometry and Morita equivalence. ArXiv:math/0402347 [math.SG] (2004).
[3] Catren G.: Quantum Foundations in the Light of Gauge Theories. To appear in C. de Ronde, S. Aerts and D. Aerts (eds.), Probing the Meaning of Quantum Mechanics: Physical, Philosophical,and Logical Perspectives, World Scientific (2014).
[4] Catren G., *Can Classical Description of Physical Reality be Considered Complete?* In M. Bitbol, P. Kerszberg and J. Petitot (eds.), *Constituting Objectivity: Transcendental Approaches of Modern Physics*, The Western Ontario Series in the Philosophy of Science, Vol. 74, Springer-Verlag, Berlin, 375-386 (2009).
[5] Catren G., *On Classical and Quantum Objectivity*, Foundations of Physics, 38, 470-487 (2008).
[6] Dirac P.M., *Lectures on Quantum Mechanics*. Dover Publications, New York (1964).
[7] Guillemin V., Sternberg S., *Geometric Quantization and Multiplicities of Group Representations*, Invent. math., **67**, 515-538 (1982).
[8] Henneaux M., Teitelboim, C. *Quantization of gauge systems*, Princeton University Press, New Jersey (1994).
[9] A.A. Kirillov, *Lectures on the Orbit Method*, Graduate Studies in Mathematics, Vol. 64, AMS (2004).
[10] Kostant B., Sternberg S., *Symplectic Reduction, BRS Cohomology and Infinite Dimensional Clifford Algebras*, Annals of Physics 176, 49-113 (1987).
[11] Landsman N.P., *Mathematical Topics Between Classical and Quantum Mechanics*, Springer Monographs in Mathematics, Springer-Verlag, New York (1998).
[12] J.E. Marsden, T.S. Ratiu, *Introduction to Mechanics and Symmetry* 2^{nd} edition. Springer-Verlag, New York (1999).
[13] J.E. Marsden, A. Weinstein, *Reduction of Symplectic Manifolds with Symmetry*, Reports on Mathematical Physics 5, 121–130 (1974).
[14] J.-M. Souriau, *Structure of Dynamical Systems. A Symplectic View of Physics*, Birkhäuser Boston (1997).
[15] Weinstein A., *Symplectic Geometry*, Bulletin (New Series) of the American Mathematical Society, Vol.5, N°1 (1981).
[16] Xu, P.: Classical Intertwiner Space and Quantization. Commun. Math. Phys. 164, 473–488 (1994).
[17] Xu, P.: Morita equivalence of Poisson manifolds. Commun. Math. Phys. 142, 493–509 (1991).

Gabriella **Crocco** (CEPERC) **July, 18, 15h05 – 15h40, Room 408, Epistemology and Philosophy**

Kurt Gödel philosopher: from logic to epistemology

Kurt Gödel left Philosophical Remarks in his Nachlass that he himself entitled Max Phil. The opus originally comprised 16 notebooks but one has been lost. The content is on the whole the outline of a rational metaphysics that allows us to relate the different academic disciplines to each other and in particular logic, mathematics, physics, biology and theory of knowledge.

The notion of time is most interesting for Gödel because it is a subject that connects humanities with the sciences. Therefore he engages with it quite often and quite intensely. This is also true for the concept of force. His transdisciplinary approach is to contemplate 'force' as a notion in physics (gravitation and quantum mechanics), as a notion in psychology (affects and emotions) and as a notion in biology, albeit he has a specific interest in physics concerning the concept of force. He is looking for an interpretation of the concept that would allow him to align the theories of relativity and quantum mechanics. Besides that the preoccupation with light quantum gives Gödel an opportunity to reflect on the differences between light and matter. We will present the main structure of Max-Phil, which as been partially transcribed and translated by a international team funded by the ANR project BLA -09-13 and focus on some remarks concerning the relationship between mathematics and physics.

Amilcar **de Queiroz** (IF-UnB & DFTUZ) **July, 18, 14h30 – 15h05, Room 408, Epistemology and Philosophy**

Symmetry, Physical Theories and Theory Change

We discuss the problem of theory change in physics. We propose a characterization of the concept of a theory in physics based on symmetries. The proposed characterization is compatible with the modern ideas in philosophy of science, e.g. the semantic approach to a scientific theory. Our approach is conceptually simple. It also allows an analysis of the problem of the mathematical structure and hints at a logic of discovery. As a case-study we consider the theory of kinematics of particles in distinct space-time backgrounds. The problem of theory change can be framed in terms of the notions of Inonu-Wigner contraction/extension of groups of symmetry. The notions presented here are strongly based on the notorious Bargmann-Wigner program.

The talk is based on joint work with Marc Lachieze-Rey and Samuel Simon [1] .

References

[1] M. Lachieze-Rey, A. de Queiroz, S. Simon, *Symmetry, Physical Theories and Theory Changes*, *to be published.*

Philipp **Hoehn** (PI) **July, 16, 15h05 – 15h40, Room 408, Epistemology and Philosophy**

A novel approach to characterising quantum theory based on limited information and complementarity

The last decade has seen a wave of reconstructions and characterizations of quantum theory using the formalism of generalized probability theory. In this talk, we shall outline a novel (operational) approach to characterizing and reconstructing quantum theory which gives primacy to limited information and complementarity rather than the probability structure. In particular, we consider an observer interrogating a system with binary questions and analyze the consequences of (1) a postulate asserting a limit on the (simultaneous) information the observer can acquire about the system, and (2) a postulate asserting the existence of complementarity on the set of possible questions. We explain how the ensuing compatibility and complementarity structure of the binary questions implies many features of qubit quantum theory in an elegant way (e.g. three-dimensionality of the Bloch sphere, the entanglement structure of two qubits, absence of third or higher order interference and many other features). Time permitting, we shall also sketch how this program can be completed to a full reconstruction of quantum theory by adding further ingredients.

Joseph **Kouneiher** (UNS) **July, 15, 15h40 – 16h15, Room 408, Epistemology and Philosophy**

Roots and prespective of Bergmann-Einstein scalar tensor theory: the unpublished paper

In 1938 long time before Dicks, Branes and Jordan work on scalar-tensor theory, Einstein and Bergmann introduce the modern viewpoint in which a four-dimensional theory that coincides with Einstein-Maxwell theory at long distances is derived from a five dimensional theory with complete symmetry among all five dimensions. But then they drew back, modifying the theory in a way that spoiled the five-dimensional symmetry and looks contrived to modern readers. The reason was that the more symmetric version of the theory predicts the existence of a new long range field (a massless scalar field), a prediction which Einstein and Bergmann refuse to admit.

We know today that, with their similar, but slightly different predictions for physical phenomena, scalar-tensor theories turned out to be the first significant challenge to Einstein's theory in over forty years. But as it turned out, standard Einstein theory fared better in these tests than any of the alternatives. In consequence, in the 1970's, interest in these alternative theories dropped dramatically. However, from the 1980's on, new discoveries and theories have led to renewed interest in scalar-tensor gravity.

In this lecture I'll back to Begmann-Einstein paper and explain the issue of their drew back and the epistemological statut of the scalar tensor kind theories with respect to the last observations.

Jean-Pierre **Luminet** (LUTH) **July, 15, 14h30 – 15h05, Room 408, Epistemology and Philosophy**

Lemaître's Big Bang

We provide an epistemological analysis of the developments of relativistic cosmology from 1917 to 1965, based on the seminal articles by Einstein, de Sitter, Friedmann, and a special focus on Georges Lemaître, the true father of Big Bang theory. In particular we solve the controversy about the so-called Hubble's law, that was first presented in a Lemaître's article of 1927 published in French, but disappeared in its English translation of 1931. It appears that most of the ingredients of the present-day standard cosmological model, such as the accelation of the expansion due to a repulsive dark energy, the interpretation of the cosmological constant as vacuum energy or the possible non-trivial topology of space, had been anticipated by Lemaître, although his papers remain desperately unquoted.

Martín **López-Corredoira** (IAC) **July, 15, 15h05 – 15h40, Room 408, Epistemology and Philosophy**

The Twilight of the Scientific Age

There are some symptoms which indicate a decline of our scientific culture. First, our society is drowned in huge amounts of knowledge. Most of it is about research of little importance to progress our world view or produces no advances in the basic fundamentals of pure science. Instead, we invent countless technical applications or investigate secondary details. Second, in the few fields where some important aspects of unsolved questions have arisen, powerful groups of administrators of science control the flow of information. They have inherent biases resulting in a preference for consensus truths, rather than having objective discussions within a scientific methodology. This process gives few guarantees that we are obtaining solid new truths about nature. Finally, should the current scientific process continue the way it is, individual creativity is condemned to disappear. Indeed, truly creative scientists are substituted by large corporations of administrators and politicians of science specialised in searching ways of getting money from States in megaprojects with increasing costs and diminishing returns.

Constructive Identities for Physics

In his classical paper "On Sense and Reference" [1] Frege asks: In which sense the Morning Star (MS) and the Evening Star (ES) are the same planet Venus? As Frege observes the assertion of identity MS=ES unlike the assertion of identity MS=MS (or MS=MorningStar) has empirical content and in this respect is not trivial. So it is unclear how the same notion of identity may apply in these two very different cases. Frege solves the problem by distinguishing between the sense and the reference of a given linguistic expression: although sentences MS=MS and MS=ES have the same reference "true" they still have different senses (i.e., different meaning).

Notice that Frege's example is not purely linguistic: in his time similar questions concerning identities of some comets and asteroids remained open; in today's astronomy the identification of new astronomical sources is never given for free but always has a complicated procedural character. Although Frege managed to explain how the identity MS=ES can hold in principle, his theory of identity provides no clue to how this or any other identity occurring in empirical sciences can be possibly grounded and justified. Since Frege's theory does not take the issue of empirical justification into account it remains largely irrelevant to the practice of empirical sciences. Given that the naive pretheoretical understanding of identity proves insufficient at least in some areas of the modern science (think about the particle physics) the need of a new formal approach to identity in physics and other empirical sciences seems me obvious.

In this paper I develop a constructive approach to identity in physics based on Martin-Löf's Constructive Type theory [2] and Voevodsky's Homotopy Type theory [3]. While earlier attempts to modify the classical identity were mostly motivated by the idea of its 'weakening' (as in the case of Krause's theory of quasi-sets, for example), the Homotopy Type theory allows for a view on identity as a construction from available empirical data and theoretical predictions/retrodictions. Suppose after Frege that identities of MS and ES are somehow fixed beforehand. This means that one is in a position to identify two independent observations of MS as observations of one and the same object; similarly for ES. In Martin-Löf's theory such presupposed identities are called definitional, while the non-trivial identity MS=ES counts as propositional. In order to establish proposition MS=ES one uses available observational data (along with a theory allowing for predictions and retrodictions of future and past positions positions of celestial bodies) and reconstructs a continuous path (trajectory) from MS to ES. In the classical celestial mechanics such a continuous trajectory indeed qualifies as the wanted identity proof, namely, as the wanted evidence of the fact that MS and ES is in fact one and the same planet continuously moving from its morning position to its evening position.

Modern physics provides contexts where such 'identity paths' are multiple and support non-trivial homotopic structures. Two obvious examples are gravitational lensing and Feynman path integrals (interpreted in terms of multiple paths of the same particle). In both these cases the identification (of sources and particles correspondingly) involves not only paths but also their homotopies (i.e. 'paths between paths' or '2-paths'). Thus in these cases the 2nd order identities (in the sense of Martin-Löf's theory) also acquire a physical meaning. Whether still higher-order identities may equally have some physical meaning remains a research question. A recent work by Schreiber [4] where higher-order identities are understood as gauge transformations suggests the answer in positive. Pushing this line one may tentatively consider the Homotopy type theory as a general logico-mathematical framework for representing physical objects: in this framework objects are represented by higher-order homotopy groupoids, which determine the objects' identity types and also their topological properties.

Tentative applications of higher identity types in empirical contexts help one to clarify the distinction between the definitional and the propositional identity Martin-Löf's theory from an epistemological standpoint. Admittedly one cannot proceed a scientific reasoning without taking some notion of identity for granted. In Martin-Löf's theory this role is played by the definitional identity. However there is no reason to consider the definitional identity as fundamental. We treat the identity MS=MorningStar as definitional simply because we have decided (after Frege) not to analyze the way in which different phenomena observed at different times by different people are identified as observations of the same Morning Star. In a different context the non-trivial empirical character of this identity can be similarly taken into account. Thus a definitional identity has the character of explicit assumption (that can be questioned and analyzed if needed) rather than that of ultimate foundation.

References

[1] G. Frege, *On Sense and Reference*, in: Translations from the Philosophical Writings of Gottlob Frege, ed. by Geach and M. Black, Oxford: Basil Blackwell 1952, pp. 56-78.
[2] P. Martin-Löf, *Intuitionistic Type Theory (Notes by Giovanni Sambin of a series of lectures given in Padua, June 1980)*, Napoli: BIBLIOPOLIS, 1984
[3] V. Voevodsky, *Homotopy Type Theory: Univalent Foundations of Mathematics*, Institute for Advanced Study (Princeton) 2013; available at http://homotopytypetheory.org/book/
[4] U. Schreiber, *Quantization via Linear homotopy types*, arXiv:1402.7041

Jérôme **Rosanvallon** (Paris 7) **July, 16, 15h40 – 16h15, Room 408, Epistemology and Philosophy**

Quantization, spatiotemporalization and pure variation

Understand the intrinsic physical meaning of quantum formalism leads ontologically to admit that one fundamental side of reality is purely contradictory, irreducibly random, objectively indeterminate and intrinsically independent of relativistic space-time. It means also that physical reality has another fundamental side, i.e. space-time, and that both are irreducible to each other. Quantum reality, discretized by the Planck constant, assume coherent states and partially ordered variables (that are commutative or not), while on the other side, relativistic space-time, structured by the speed of light, assume coherent variables and partially ordered states (that are causally related or not).

From this point of view, fields would be only a derived mixture of these two sides. But quantum reality and relativistic space-time seem to be mixed in two kinds of fields themselves irreducible to each other. If, on one hand, quantum field theory has already formalized the way that quantum reality locates, evolves and interacts on a relativistic background, on the other hand, quantum gravity tends to formalize the way that smooth and causally ordered space-time emerges on a quantum background. But no unification of the two fundamental sides of reality must be waited at this derived level. Unification could perhaps intervene only upstream, in a pure variation preceding and underlying its double distinction in variables and states of variation, i.e. its quantization or its localization and their derived mixtures.

John **Stachel** (CES) **July, 17, 14h30 – 15h05, Room 408, Epistemology and Philosophy**

Do Quanta Need a New Logic?

What is Logic? My answer consists of three steps: Logic is about Language, Language is about the World. Panlogism is the attempt to "short circuit" this process by identifying the real object and the "concrete-in- thought." It leads to the assertion: Logic is about the World. If we abandon panlogism, we see that quantum logics (note the plural!) are just different ways of reformulating the same content. The danger: is that, If we accept the idea of one unique quantum logic, that provides all the answers, this prevents us from confronting the real questions about quantum mechanics.

Roman **Sverdlov** (IISER) **July, 16, 17h35 – 18h10, Room 408, Epistemology and Philosophy**

Describing many-particle QM as well as QFT in terms of "single particle" QM with one extra dimension

From ontological point of view, single particle QM makes a lot more sense than multiparticle case. After all, in case of a single particle you can claim that ψ is NOT "probability amplitude" but, rather, it is simply "classical field"; it simply HAPPENS that probability of collapse of ψ coincides with the square of its absolute value. On the other hand, in case of many particles you can not make this argument: after all, classical field lives in ordinary space, NOT in configuration space! Motivated by this, I am attempting to reduce multiparticle quantum mechanics to single particle one. I am doing this by the following trick. First, I introduce extra dimension. Then I design various "classical" objects in such a way that we have different "classical" configurations on different $x^5 = \text{const}$ hyperplane. Finally, we introduce one SINGLE quantum particle, the one referred to as "pointer", and the "pointer" takes the classical configuration from the hyperplane it resides on and makes it "come true". Thus, instead of quantizing configurations, all we have to do is quantize the location of a pointer, which reduces multiparticle QM to single particle QM. This approach is also extended to reducing quantum field theory to single particle quantum mechanics, as well; we simply replace "classical particle distribution" on the hyperplanes with "field distributions". The reference to the paper where I have done the above work is [1].

References

[1] arXiv:1309.3287

Jean-Jacques **Szczeciniarz** (Paris Diderot) **July, 17, 15h05 – 15h40, Room 408, Epistemology and Philosophy**

Category and Physics

I propose to begin an assessment of the debate on the intervention of the category theory in physics. 1- I begin by considering the classical relationship between geometry and physics using the example of Newton, of a formalism of the theory of GR and quantum mechanics. 2-I am going to show that categorical formulation provides numerous epistemological and philosophical benefits. I will then make a distinction between a local and a global reformulation. 2-I show why one must choose, and often develop a specific understanding of the theory categorized. The risk of the development of the theory of categories itself regardless of initial physical target is always incurred. At this level also the danger of leaving the physical out of it is always present. 4-I want to show how the risk itself is relevant for reasons both physical and mathematical. 5-I will discuss some relationships between geometrization and categorification. My analysis will focus on twistor theory.

Francesca **Vidotto** (IMAPP) **July, 16, 17h00 – 17h35, Room 408, Epistemology and Philosophy**

Atomism and Relationalism as guiding principles for Quantum Gravity

The research in quantum gravity has jauntily grown in the recent years, intersecting with conceptual and philosophical issues that have a long history. In this paper I analyze the conceptual basis on which Loop Quantum Gravity has grown, the way it deals with some classical problems of philosophy of science and the main methodological and philosophical assumptions on which it is based. In particular, I emphasize the importance that atomism (in the broadest sense) and relationalism have had in the construction of the theory.

References

[1] F. Vidotto, *Atomism and Relationalism as guiding principles for Quantum Gravity*, [physics.hist-ph/1309.1403].
[2] C. Rovelli and F. Vidotto, *Covariant Loop Quantum Gravity. An elementary introduction to Quantum Gravity and Spinfoam Theory*, Cambridge University Press, Cambridge U.K. (2014).

Hervé **Zwirn** (CNRS / CVT) **July, 16, 14h30 – 15h05, Room 408, Epistemology and Philosophy**

Decoherence and the measurement problem

The problem of measurement taken at face value shows clearly that there is an inconsistency inside the quantum formalism. The phenomenon of decoherence is often presented as a solution to it. A widely debated question is to decide between two different interpretations. The first one is to consider that the decoherence process has the effect to actually project a superposed state into one of its classically interpretable component, hence doing the same job as the reduction postulate. For the second one, decoherence is only a way to show why no macroscopic superposed state can be observed and so, to explain the classical appearance of the macroscopic world, while the quantum entanglement between the system, the apparatus and the environment never disappears. In this case, explaining why only one single definite outcome is observed remains to do. We will examine arguments for and against both interpretations and will defend a position according to which the outcome that is observed is relative to the observer in close parallel to the Everett interpretation and sharing some similarities with the Rovelli's relational interpretation, while different on important points.