Book of Abstracts (last updated: Juli 07)

't Hooft 2019 – From Weak Force to Black Hole Thermodynamics and Beyond

(the authors are in alphabetical order)

Jeremy Butterfield & Henrique Gomes
On the empirical significance of symmetries

In this talk, we will adjudicate a recent philosophical debate about the empirical significance of symmetries. In the background of our discussion is a framework using a connection-form in the field-space of gauge theories. (It was recently developed by one of us and collaborators: Gomes & Riello JHEP 2017,Gomes & Riello PRD 2018, Gomes, Hopfmuller, Riello NPB 2019.)

In the debate, all hands agree that some symmetries---the paradigm example being a velocity boost of Galileo's ship---have a direct empirical significance. Namely, one can observe that processes in the cabin unfold in the same way, whether or not the ship is moving relative to the quay. The debate concerns whether symmetries usually called 'gauge'---the paradigm example being a gauge transformation in classical electromagnetism---can have a similar significance, witnessed by an analogue of Galileo's ship. In this debate, some (e.g. Brown, Brading) say No: this is the traditional position. But some (e.g. Greaves, Wallace) say Yes: a heterodox position.

We maintain that there are two main relevant distinctions, which cut across one another: (i) whether a transformation is applied to the world as a whole, or only to a subsystem of the world; (which we label: 'universal' vs. 'regional'); (ii) whether a transformation depends on an infinite number of parameters, e.g. by being specified by an arbitrary smooth function; or depends on only a finite number of parameters; (which we label: 'malleable' vs. 'rigid'). Thus we avoid the usual words 'global' and 'local', since they are ambiguous. Namely: 'global' is ambiguous between 'universal' and 'rigid'; and 'local' is ambiguous between 'malleable' and 'regional'.

With this jargon, we can state our main idea about the debate as follows. The heterodox position of Greaves and Wallace is correct in spirit, in that regional transformations can indeed have a direct empirical significance. But they are wrong 'in the letter', in that they take the transformations at issue to be malleable (which they call 'local'): while in fact, they are rigid, in both classical electromagnetism and Yang-Mills. That is: there can be only a finite dimensional subgroup of transformations that bear empirical significance.

Elena Castellani
Monopoles and duality: a historical-philosophical perspective

The history of electric-magnetic duality and its generalizations provides an instructive case study for the philosophical discussion on theory building and assessment. The talk is devoted to highlighting the role played in this regard by the convergence and interplay of different ideas and research threads in the developments of (generalized) electromagnetic duality. To this aim, I will focus, in particular, on some seminal conjectures and results in the 1970s leading to remarkable advances in fundamental physics.

Dennis Dieks
Identical quantum particles as distinguishable objects

In classical physics particles are objects that can be distinguished from each other by their physical properties: two particles differ at least in their positions. By contrast, in quantum mechanics the standard view is that particles of the same kind (``identical particles'') are physically indistinguishable, because the (anti)symmetrization postulates imply that they are all in exactly the same state. But this indistinguishability doctrine is problematic: Particle indistinguishability is irreconcilable not only with the everyday meaning of ``particle'' but also with how this term is used in the actual practice of physics. Moreover, the standard doctrine implies that quantum particles of the same kind remain indistinguishable even in the classical limit so that quantum particles can never become (approximately) classical.
In the talk I will outline a conception of quantum particles that avoids these difficulties. According to this view particles in quantum theory are not fundamental but emergent. However, in situations where the particle concept becomes applicable at all, quantum particles---identical or not---are physically distinguishable.

Jeroen van Dongen
Gerard ’t Hooft and the Black Hole Information Paradox

The black hole ‘information paradox’ was introduced by Stephen Hawking in 1976. It suggested that the evaporation of a quantum black hole could not be in agreement with familiar unitary evolution laws of quantum mechanics. We present the history of the ensuing debate and place the contributions of various actors within the context of the various cultures of theory from which they originated. Why was Hawking’s position originally not considered controversial, and was opposition, in particular by Gerard `t Hooft, critically received? In this historical-philosophical talk, we will revisit some of the arguments and opinions, and reconstruct the dynamics of the 1980s and 1990s.

Michael Duff

Metric reversal invariance

Inspired by G. ’t Hooft and S. Nobbenhuis, we consider the signature reversing transformation of the metric tensor in spacetimes with signature (S, T) induced by the chiral transformation of the curved space gamma matrices which also induces a spacetime orientation reversal. We conclude that it is a symmetry only for chiral theories with $S - T = 4k$, with k integer. Gravitational theories require dimensions $D = 4k + 2$ with T odd, for which the symmetry is preserved by coupling to odd rank field strengths. In $D = 10$, for example, it is a symmetry of Type IIB supergravity but not Type IIA. Although ruling out a cosmological constant in $D=4k+2$, one may appear after spontaneous compactification to lower dimensions. We also respond to criticisms of Bars, Steinhardt and Turok.

Sebastian de Haro
A Conceptual Analysis of Black Hole Entropy in String Theory

The microscopic state counting of the extremal Reissner-Nordström black hole performed by Andrew Strominger and Cumrun Vafa in 1996 has proven to be a central result in string theory. In this historical-philosophical talk, I will present the argument in its contemporary context, and I will analyse its rather complex conceptual structure. In particular, I will identify the various inter-theoretic relations, such as duality and linkage relations, on which it depends. I further aim to make clear how it engendered subsequent work that intended to strengthen the string-theoretic analysis of black holes. I will briefly discuss its relation to the formulation of the AdS/CFT correspondence, and I will give the familiar reinterpretation of the entropy calculation in the context of AdS/CFT. Finally, I will briefly analyse the question of emergence of the black hole from a collection of D-branes.

Gerard ‘t Hooft
How exact are the laws of nature

Quantum mechanics consists of a set of laws that yield outcomes in the form of probabily distributions. The laws seem to be precisely formulated, although, when merged into Einstein's theory of special relativity, that leads to quantised fields, QFT, which necessitates various approximation procedures that sometimes give the impression that high precision is lost. Things get much worse when we go to the theory of general relativity, where curvature of space and time seems to generate quite a bit more vagueness.

Now, in attempting to understand better what quantum mechanics really means in the world of physical particles, we have coined models based on determinism. These models only make sense if applied with infinite precision. This requires a change of paradigm that is difficult to defend against prejudices that have established firm ground in the science community. Yet determinism may become an inevitable ingredient for new generations of theories.

Ted Jacobson

Gravitational thermodynamics of de Sitter spacetime and other causal diamonds

Can horizon thermodynamics---and ultimately quantum gravity---be quasi-localized? A special case is the static patch of de Sitter spacetime, known since the work of Gibbons and Hawking to admit a thermodynamic equilibrium interpretation. I shall explain why this interpretation makes sense only if a *negative* temperature is assigned to the state, how that is compatible with the positive Gibbons-Hawking temperature, and how these notions generalize to any maximally symmetric causal diamond. Next I'll briefly discuss the statistical mechanics of de Sitter spacetimes using the Brown-York boundary method, and will report on progress understanding the reduced phase space of 2+1 dimensional causal diamonds and its quantization.

Klaas Landsman

Randomness? What randomness?

Since randomness is merely a family resemblance, it is worth discussing the precise sense in which quantum theory is (allegedly) random. One possible meaning could be algorithmic (or Kolmogorov-Chaitin) randomness, which however is such an elusive concept that it may not be possible to apply it to anything. This talk will be seeking, containing many questions and few answers, but the discussion is even relevant if the world is ultimately deterministic!

Juan Maldacena

Black holes, entanglement and wormholes

We will review developments over the past decade on the connection between entanglement and spacetime geometry. We will start by describing the Ryu-Takayanagi entropy formula, and its quantum generalization. We will distinguish between pure state black holes and entangled black holes. Finally we will describe recent ideas for understanding the connection between the evaporating geometry of the black hole and the corresponding quantum state.

Tim Maudlin

Bell's Other Assumption(s)

For rhetorical purposes, it is tempting to say that Bell's Theorem follows from only one assumption: Bell Locality. One has to be a bit meticulous in describing that assumption, but the result appears irresistible: since the plain data for experiments done at space-like separation violate the inequality, one must accept the physical reality of Bell-non-locality. Like it or not, non-locality is here to stay.

Of course, many people don't like it, and have tried hard to draw completely different conclusions from the data. In some circles it is popular to claim that one can avoid Bell's conclusion by denying a tacit premise called "realism", although exactly what "realism" states and exactly where the assumption appears mathematically in Bell's proof is never made clear. Even so, the argument for a failure of locality does rest on some further assumptions which can be located and articulated. In particular, Bell uses an assumption called “Statistical Independence”, so denying that assumption might appear to be a way to avoid the physical reality of non-locality.

I will argue otherwise. Some assumptions in any physical argument have a sort of “transcendental” status: denying them would make physics—or empirical science in general—impossible. Once one clearly understands what the statistical independence assumption is, it becomes clear that one cannot abandon it and still pursue empirical scientific inquiry.

Laura Mersini-Houghton

Unsettled Problems in Cosmology

Despite significant breakthroughs in theoretical physics and in precision cosmology, we are still at a loss when confronting the most fundamental questions about our universe: its origin, its ultimate destination, and its arrow of time.

The problem of an exquisitely special origin, that of selecting a high energy initial state for our universe, seems to be an unavoidable consequence of the second law of thermodynamics. I will argue that a special origin will remain a problem for any initial state, even for a low energy one, if we insist on comparing entropy states within a single universe. If we drop the single universe assumption, the answer to the origin mystery can be derived from a quantum multiverse.

The origin problem is closely related to the nature of time and the emergence of time's arrow.

The end of the universe is determined by dark energy, which we don't understand.

The amount of dark energy, whatever its nature, in our universe seems fine-tuned to allow for observers to exist and 'watch' the universe. Constants of nature seem fine-tuned for the same reason.

Considering the difficulty of the problems listed here, a popular way out of the conundrum has been to appeal to the 'anthropic principle'. Incorrectly, even the multiverse is viewed as grounds for justifying anthropic selections of a universe with observers. I will show that one can have habitable universes for a wide range of constants of nature and of vacuum energies. Therefore, we need to derive the answer to these fundamental questions rather than use anthropic arguments.

Malcolm Perry

Soft Black Hole Hair

The black hole information paradox remains a central issue in our understanding of gravity. However, one of the reasons for believing that there is a problem are the black hole uniqueness theorems. Soft black hole hair shows that the black hole uniqueness theorems are in need of modification. I will discuss some aspects of soft hair, how it can be used to describe black hole entropy and the beginnings of how to understand how soft hair can store some of the information associated with material absorbed by a black hole. Finally, I will explain what further needs to be done to see if these ideas can resolve the information paradox.

Dean Rickles
Planar Diagrams, Dual Models, and QCD

This talk is an historical overview of an interesting, though rather short-lived episode involving the relationship between dual resonance models (the old string [and pre-string] theory of hadrons) and QCD (and local field theory more generally). The central focus is ’t Hooft’s ‘planar diagram theory’ and his introduction of the large N limit as a means of linking QCD and string theory. I also argue that this link (a kind of early gauge/string duality) was in fact a further strong reason behind the uptake of QCD (i.e. beyond the well-known hard scattering and other empirical results) and field theory over the dual models, the latter being encompassed in the former. I also make some more philosophical remarks about these dualities and their role in physical theories.

Carlo Rovelli
Black holes can tunnel into white holes

A scenario for the evolution of black holes at the end of their evaporation is receiving much attention: the black hole quantum tunnels into a long living Planck size white hole. I review the arguments supporting this scenario, the potential objections and their answers. I also briefly mention possible phenomenological implications of this scenario, in particular for dark matter."

Leonard Susskind

GR=QM

I will review the surprising parallels between quantum mechanics and gravity that have been uncovered in recent years such as the ER=EPR connection and the relation between quantum complexity and the interiors of black holes. I'll also discuss the possibility of seeing quantum gravity in a lab equipped with quantum computers. I expect this will become feasible sometime in the next decade or two.

Jos Uffink
Schrödinger and the prehistory of the EPR argument.

Although Schrödinger only coined the term "entanglement" (Verschränkung) in 1935, he had been worrying about the phenomenon of (what we now call) entanglement for composite systems since 1927. Indeed, he gave up on his original interpretation of the wave function precisely for this reason. At that time, he thought that Born's statistical interpretation of the wave function did not suffer from the same problem. In November 1931, his unpublished notebooks show that, in response to a lecture in Berlin by Einstein on the photon box experiment, he already developed all essentials of what we now know as the EPR argument, (Einstein, Podolski and Rosen, 1935). I argue that Schrödinger’s role in the development of this argument has not yet been sufficiently appreciated by historians of physics.

Also, I will comment on the differences between Schrödinger’s and Einstein’s views on the conclusions to be drawn from this argument.

Erik Verlinde

Quantum detailed balance and shockwaves near black hole horizons.

Chris Wetterich

Quantum mechanics and quantum computing from classical bits

Probabilistic or deterministic operations on Ising spins or classical bits can perform the unitary time evolution of quantum mechanics, or the unitary gates of quantum computing. Quantum subsystems obtain from classical statistical systems by restriction to a subset of correlation functions. The quantum formalism with the density matrix or wave functions, and non-commutative operators for observables, arises naturally in this setting. We propose a possible realization of Q qubits by 3Q classical bits. We discuss static memory materials based on equilibrium states of generalized Ising models that show interference effects in the bulk, depending on boundary conditions. Neural networks can learn quantum gates. We argue that quantum mechanics can be embedded in classical probabilistic theories, without the need of separate axioms.