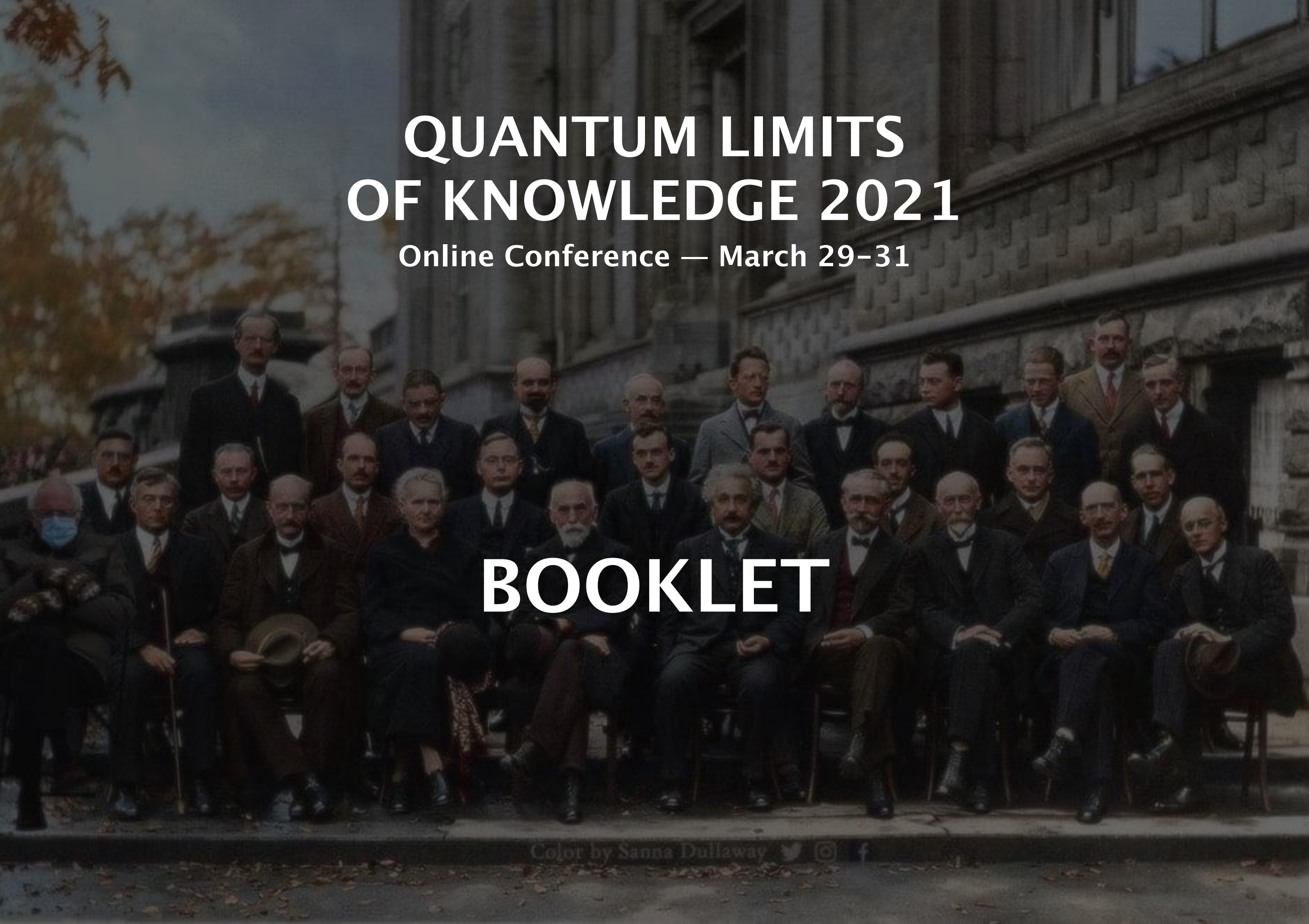
QUANTUM LIMITS OF KNOWLEDGE 2021

Online Conference — March 29-31

BOOKLET



The idea for the QLK21 comes from the success of the first edition, held in Copenhagen in 2019. For this edition, the program committee is composed by: Alexia Auffèves, Guido Bacciagaluppi, Cyril Branciard, Hans Briegel, Jeremy Butterfield, Chris Fuchs, Nicolas Gisin, Vincent Lam, Cristian Mariani, Klaus Mølmer, and Eugene Simon Pozik. The topics selected are: (I) *Varieties of Realism in Quantum Physics,* (II) *Space, Time, and Quantum Mechanics*. The conference will feature 16 talks from prominent scholars, philosophers and physicists alike, and two round tables.

This event is organized by:
Institut Néel (CNRS, Grenoble) &
Chair of Excellence in Philosophy of Quantum Physics (UGA Grenoble).

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Abstracts

Ordered by authors

How to avoid the appearance of a classical world in gravity experiments

Markus Aspelmeyer
University of Vienna

TBA

Bell Inequality Violation and Relativity of Pre- and Postselection

Guido Bacciagaluppi
& Ronnie Hermens
Utrecht University

The Bell inequalities can be violated by postselecting on the results of a measurement of the Bell states. If information about the original state preparation is available, we point out how the violation can be reproduced classically by postselecting on the basis of this information. We thus propose a variant of existing experiments that rules out such alternative explanations, by having the preparation and the postselection at spacelike separation. Unlike the timelike case where one can sharply distinguish Bell inequality violations based on pre- or postselection of a Bell state, in our scenario the distinction between these physical effects becomes foliation-dependent. We call this 'relativity of pre- and postselection'.

Present and future precision tests of spontaneous wave function collapse models

Angelo Bassi
University of Trieste

Quantum mechanics is grounded on the superposition principle, which is the source both of its tremendous success and technological power, as well as of the problems in understanding it. The reason why superpositions do not propagate from the microscopic to the macroscopic world are unclear. Spontaneous wave function collapse models have been formulated to take into account a progressive breakdown of quantum superpositions when systems are large enough; they do so by modifying the Schrödinger dynamics, and therefore they are empirically testable. Deviations are tiny, and require precision measurements. I will review the most recent tests of such models, with a focus on gravity-related ones.

On a variety of realism that fits with an anti-realist approach of quantum mechanics

Michel Bitbol
Ecole Normale Supérieure

QBism (Quantum Bayesianism or Quantum Bettabilitarianism) has an instrumentalist, and therefore anti-realist, ancestry. Yet, it accommodates a non-conventional form of realism that still has to be assessed. Christopher Fuchs calls it "participatory realism". It is a form of realism for someone who cannot be dissociated from the "reality" she explores. Here, I explore several features and consequences of "participatory realism". I first connect it with the archetypal definition of "anti-realism" by Michael Dummett. I then explore the atypical connection between "reality" and theoretical symbolisms it involves: in "participatory realism", representationalism is discarded, and normativism is advocated instead. I finally compare "participatory realism" with other alternative forms of realism, such as relational realism.

Time in Physics and Intuitionistic Mathematics

Nicolas Gisin
University of Geneva

Physics is formulated in terms of timeless axiomatic mathematics. However, time is essential in all our stories, in particular in physics. For example, to think of an event is to think of something in time. A formulation of physics based of intuitionism, a constructive form of mathematics built on time-evolving processes, would offer a perspective that is closer to our experience of physical reality and may help bridging the gap between static relativity and quantum indeterminism. Historically, intuitionistic mathematics was introduced by Brouwer with a very subjectivist view where an idealized mathematician continuously produces new information by solving conjectures. Here, in contrast, I'll introduce intuitionism as an objective mathematics that incorporates a dynamical/creative time and an open future. Standard mathematics appears as the view from the "end of time" and the usual real numbers appear as the hidden variables of classical physics. Classical mathematics appears as intuitionistic mathematics seen from the "end of time". Similarly, determinism appears as indeterminism seen from the "end of time". Often, it is argued that relativity is incompatible with indeterminism. Hence, at the end of this presentation I'll argue that these incompatibility arguments are based on unjustified assumptions and present the "relativity of indeterminacy".

Quantum Theory and Scientific Realism

Owen Maroney
Oxford University

TBA

Quantum Agents and the Thermodynamics of Machine Learning

Gerard Milburn
Centre for Engineered Quantum Systems
& The University of Queensland

General purpose analogue machine learning has a history that predates digital computing with the first important results published by Shannon in 1941. In this talk I discuss the thermodynamic constraints on analogue machine learning based on Hopf bifurcations in both classical and quantum systems. This makes clocks central to machine learning. In the classical case dissipation and thermal noise are essential to learning. In the quantum case learning can proceed at zero temperature due entirely to quantum noise in the form of spontaneous emission and tunnelling and new modes of operation emerge based on using quantum sensors and actuators. Coherent quantum feedback offers uniquely quantum protocols not based on measurement feedback.

Two types of indeterminism in quantum correlation experiments: A branching space-times analysis

Thomas Müller
University of Konstanz
&
Tomasz Placek
Jagiellonian University Kraków

Branching space-times (BST), due to Belnap (Synthese, 1992), is a rigorous formal framework for representing indeterministic scenarios in spatio-temporal detail. BST has the resources for defining precise notions of modal and probabilistic correlations, aka funny business. Modal funny business is, to put it informally, an unexpected failure of locally possible outcomes to combine to a globally possible joint outcome. Similarly, probabilistic funny business occurs when

local outcomes have joint probabilities that do not factor in the way one would expect them to. Given these notions, BST is well suited for representing and analyzing quantum correlation experiments, which are intricate spatio-temporal arrangements that can exhibit strange correlations. In this talk, we consider only modal correlations, such as exhibited in the GHZ experiment. Ever since Einstein, Podolsky, and Rosen (1935), there has been a quest for providing extended descriptions of quantum correlation experiments that avoid the troublesome correlations by adding hidden variables. In BST, we can characterize different ways in which the given surface structure of such experiments can be extended, and for this analysis, it is crucial to spell out what it means to represent a quantum correlation experiment not just as a spatio-temporal happening, but specifically as an experiment. It turns out that in experiments, two types of indeterminism need to be explicitly distinguished. We will show in BST terms which role this distinction plays in deriving “no go” results for hidden variables.

The Status of Quantum State Realism

Wayne Myrvold
University of Western Ontario

I will argue that we have good reason to believe that distinct pure quantum states correspond to distinct physical states. Moreover, contrary to what is suggested by Quantum Bayesians, the arguments for realism about quantum states go through when the probabilities involved are taken to be subjective, if the conclusion is about the agent's beliefs: an agent whose credences conform to quantum probabilities should believe that preparation procedures with which she associates distinct pure quantum states produce distinct states of reality. The conclusion can be avoided only by stipulation of limitations on the agent's theorizing about the world, limitations that are not warranted by the empirical success of quantum mechanics or any other empirical considerations.

Three Arguments for Wave Function Realism

Alyssa Ney
University of California, Davis

Wave function realism is an interpretative framework for quantum theories which recommends taking the central ontology of these theories to consist of the quantum wave function, understood as a field on a high-dimensional space. I will present and evaluate three standard arguments for wave function realism and clarify the sort of ontological framework these arguments support.

What can quantum agents know about each other?

Renato Renner
ETH Zurich

Users of a physical theory are themselves part of the physical world. This obvious fact leads to a requirement on any physical theory that is supposed to be universally valid: The theory must be able to correctly describe the users of the theory. Quantum theory (assuming it is universally valid) thus imposes limits on our knowledge in two different ways. Firstly, when we use quantum theory to describe an experiment, we obtain constraints from the familiar Heisenberg uncertainty relation. Secondly, when we take into account that the process of using quantum theory is itself a quantum mechanical process, we encounter

other, less familiar, limits. In my talk I will try to shed some light on this second aspect, which is much less well known than the first.

How to be a realist without wave-function realism

Carlo Rovelli
Aix-Marseille University

Discussions on quantum mechanics often assume that an epistemic interpretation of the wave function (or the Hilbert-space's state) is incompatible with realism and requires an instrumentalist view of science. I show that this is a mistake. Quantum mechanics can be interpreted without makeing reference to observers, agents, or knowledge, but without wave-function realism either.

Time's Arrow of a Quantum Superposition of Thermodynamic Evolutions

Giulia Rubino
University of Vienna

A priori, there exists no preferential temporal direction as microscopic physical laws are time-symmetric. Still, the second law of thermodynamics allows one to associate the 'forward' temporal direction to a positive variation of the total entropy produced in a thermodynamic process, and a negative variation with its 'time-reversal' counterpart. This definition of a temporal axis is normally considered to apply in both classical and quantum contexts. Yet, quantum physics admits also superpositions between forward and time-reversal processes, thereby seemingly eluding conventional definitions of time's arrow. In this talk, I will demonstrate that a quantum measurement of entropy production can distinguish the two temporal directions, effectively projecting such superpositions of thermodynamic processes onto the forward (time-reversal) time-direction when large positive (negative) values are measured. Remarkably, for small values (of the order of plus or minus one), the amplitudes of forward and time-reversal processes can interfere, giving rise to entropy-production distributions featuring a more or less reversible process than either of the two components individually, or any classical mixture thereof. Finally, I will extend these concepts to the case of a thermal machine running in a superposition of the heat engine and the refrigerator mode, illustrating how such interference effects can be employed to reduce undesirable fluctuations.

A Tale of Two QBisms
(Realism more or less)

Chris Timpson
Oxford University

I will briefly recapitulate the senses in which it can be said that QBism is a realist position and a realist programme. I will then contrast what may be called Full Blooded QBism, as currently maintained by Chris Fuchs and colleagues, with a more moderate, and perhaps more defensible, QBism Lite, this being a version of QBism along the lines that I articulate in Timpson (2013, Quantum Information Theory and the Foundations of Quantum Mechanics, OUP). In particular I will explain why it seems to me that escaping the standard no-go results (especially Bell's theorem) does not require one to move so far as to Full Blooded QBism.

Quantum Gravity and Quantum Probability

Antony Valentini
Clemson University

We argue that in canonical quantum gravity there is no fundamental Born rule at the level of the Wheeler-DeWitt equation, and that an effective Born rule emerges only in the Schrödinger approximation for quantum systems on a classical spacetime background. Furthermore, we show that small quantum-gravitational corrections to the Schrödinger equation can render the Born rule unstable. These results are shown to arise naturally in the de Broglie-Bohm pilot-wave formulation of canonical quantum gravity.

On the Plurality of Quantum Theories

David Wallace
University of Pittsburgh

`Quantum theory' is not a single physical theory but a framework in which many different concrete theories fit. As such, a solution to the quantum measurement problem ought to provide a recipe to interpret each such concrete theory, in a mutually consistent way. But - with the exception of the Everett interpretation - the main extant solutions either try to make sense of the abstract framework as if it were concrete, or else interpret one particular quantum theory under the fiction that it is fundamental and exact. In either case, these approaches are unable to help themselves to the very theory-laden, level-relative ways in which quantum theory makes contact with

experiment in mainstream physics, and so are committed to major revisionary projects which have not been carried out even in outline. As such, only the Everett interpretation is currently suited to make sense of quantum physics as we find it.

Round Table I

Space, Time, and Quantum Mechanics

Chair: *Giuliano Torrengo*
University of Milan &
Autonoma Barcelona

Participants:

Vincent Lam
University of Bern

Antony Valentini
Clemson University

Carlo Rovelli
Aix-Marseille University

Round Table II

Varietes of Realism in Quantum Physics

Chair: *Claudio Calosi*
University of Geneva

Participants:

Alexia Auffféves
Institut Néel

Chris Fuchs
UMass Boston

Wayne Myrvold
University of Western Ontario

Useful Information

Due to COVID-19 Health Crisis, the QLK21 will be held online, on the platform Zoom.

All the talks will be recorded and made available from Monday April 5th, on YouTube, on the page of *Quantum Engineering Grenoble* (link here).

Here you can find more details about the first edition of the QLK, held in Copenhagen in 2019, and here you can see the special issue based on that conference.

We hope you will enjoy the QLK21!

The organizing Committee

Alexia Aufféves
Cyril Branciard
Vincent Lam &
Cristian Mariani