Die Junge Akademie

FQT08

AG Grenzen der Quantentheorie

Frontiers of Quantum Theory: Reality and Randomness

Harnack Haus, Berlin, April 28 - 30, 2008

Die Junge Akademie an der Berlin-Brandenburgischen Akademie der Wissenschaften und der Deutschen Akademie der Naturforscher Leopoldina
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This workshop: `fqt08@diejungeakademie.de`

Monday, April 28

13:00	Lunch	
14:00	Welcome	Cord Müller
14:00 – 14:45	**Anton Zeilinger**	
	Information and Quantum Information and the Foundations of Physics	
14:45 – 15:30	**Maximilian Schlosshauer**	
	The nature of quantum states and collapse: Interpretations, decoherence, and classical concepts	
15:30 – 16:15	Tea and Discussion	
16:15 – 17:00	**Brigitte Falkenburg**	chair: Walter Hofstetter
	Wave-Particle Duality in recent Quantum Optics	
17:00 – 17:45	**Klaus Hornberger**	
	Decoherence and the boundaries of the quantum world	
17:45 – 18:30	**Theo Nieuwenhuizen**	chair: Melanie Schnell
	Physical model for simultaneous measuring of non-commuting variables	
18:30 – 19:15	Discussion	
19:30	Dinner at the Harnack Haus	

Tuesday, April 29

09:00 – 09:45	**Joy Christian**	chair: Christian Fleischhack
	Physical Irrelevance of Bell's Theorem and its Variants	
09:45 – 10:30	**Carsten Held**	
	Quantum Measurement and No-Hidden-Variable-Proofs	
10:30 – 11:00	Coffee and Discussion	
11:00 – 11:45	**Harald Weinfurter**	chair: Mathias Kläui
	Loophole free Beel tests?	
11:45 – 12:30	**Immanuel Bloch**	
	Quantum Measurements and Simulations with Ultracold Atoms	
12:30 – 13:00	Discussion	
13:00	Lunch	
14:30 – 15:15	**Rainer Blatt**	chair: Philip Walther
	Quantum Information Science with Trapped Ca^+ Ions	
15:15 – 16:00	**Artur Ekert**	
	Why Everett was right and everyone else is wrong	
16:00 – 16:30	Tea and Discussion	
16:30 – 17:15	**Alain Aspect**	chair: Gerhard Ernst
	tba	
17:15 – 18:30	**Robert Griffiths**	
	Consistent Quantum Probabilities	
18:30 – 19:00	Discussion	
19:30	Conference Dinner in the "Ristorante Il Mulino"	

Wednesday, April 30

09:00 – 09:45 **Richard Gill** chair: Ulrich Schollwöck
Why Bell's theorem is still relevant and still untested

09:45 – 10:30 **Berthold-Georg Englert**
No Mist in Copenhagen

10:30 – 11:00 Coffee and Discussion

11:00 – 11:45 **Claus Kiefer** chair: Volker Springel
Quantum gravity and the probability interpretation of quantum mechanics

11:45 – 12:30 **Holger Lyre**
Realism, Scientific Realism and Quantum Interpretations

12:30 – 13:00 Discussion

13:00 Lunch

14:30 – 15:15 **Reinhard Werner** chair: Christine Silberhorn
Layers of interpretation: what should we teach?

15:15 – 16:00 Closing

Invited Speakers

Alain Aspect

Laboratoire Charles Fabry de l'Institut d'Optique, Palaiseau
alain.aspect@institutoptique.fr

Talk: Tuesday 16:30 – 17:15

Rainer Blatt

Institut für Experimentalphysik, Universität Innsbruck
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Talk: Tuesday 14:30 – 15:15

Quantum Information Science with Trapped Ca^+ Ions

Trapped strings of cold ions provide an ideal system for quantum information processing. The quantum information can be stored in individual ions and these qubits can be individually prepared; the corresponding quantum states can be manipulated and measured with nearly 100% detection efficiency. With a small ion-trap quantum computer based on up to eight trapped Ca^+ ions as qubits we have generated genuine quantum states in a pre-programmed way. In particular, we have generated GHZ and W states in a fast and scalable way and we have demonstrated for the first time a Toffoli gate with trapped ions which is analyzed via state and process tomography. Entanglement swapping was demonstrated on demand and high fidelity CNOT-gate operations are investigated towards fault-tolerant quantum computing. As an application to quantum metrology, with Bell states as a resource, entangled states are used for quantum metrology on an optical clock transition.

Immanuel Bloch

Johannes Gutenberg Universität Mainz, Germany
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Talk: Tuesday 11:45 – 12:30

Quantum Measurements and Simulations with Ultracold Atoms

Joy Christian

Wolfson College, Oxford University, UK
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Talk: Tuesday 09:00 – 09:45

Physical Irrelevance of Bell's Theorem and its Variants

Bell's theorem is generally believed to have proved that no physical theory can be reconciled with the notion of a complete local reality espoused by Einstein, Podolsky, and Rosen. However, I will show that the framework of local realistic theories employed by Bell and his followers in the proofs of their theorems is itself far from complete. In fact, by judiciously completing the framework used by Bell to represent the elements of physical reality, his theorem can be rendered irrelevant for the notion of local realism. I will demonstrate this fact by means of an explicit counterexample to Bell's theorem, which is based on the system of directed real numbers developed by Grassmann and Clifford. In particular, I will show that a strictly local, purely deterministic, and manifestly realistic Clifford-algebraic model exists that exactly reproduces every prediction of quantum mechanics relevant for the EPR-Bohm type experiments, without necessitating either remote contextuality or backward causation. The model thus renders the notion of entanglement amenable to a statistical interpretation, and opens up the possibility of a fully deterministic, local, and realistic underpinning of the quantum phenomena.

Artur Ekert

Mathematical Insitute, University of Oxford, UK, and
Director at Centre for Quantum Technologies, National University of Singapore
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Talk: Tuesday 15:15 – 16:00

Why Everett was right and everyone else is wrong

Berthold-Georg Englert

Department of Physics, National University of Singapore
phyebg@nus.edu.sg

Talk: Wednesday 09:45 – 10:30

No Mist in Copenhagen

I will argue that there are no problems with standard quantum mechanics. In particular, the so-called measurement problem is nothing to worry about, and there is nothing paradoxical about Schrödinger's poor cat.

Brigitte Falkenburg

Institut für Philosophie, Technische Universität Dortmund
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Talk: Monday 16:15 – 17:00

Wave-Particle Duality in recent Quantum Optics

After giving a short survey on the history of wave-particle duality and the pragmatic approach of many physicists to the preparation of waves and the detection of particles, recent "Which Way" experiments of quantum optics are discussed.

Richard Gill

Mathematical Institute, Leiden University
gill@math.leidenuniv.nl

Talk: Wednesday 09:00 – 09:45

Why Bell's theorem is still relevant and still untested

I will argue that Bell's theorem is still as relevant as ever. I will also argue that Bell's inequality has never been violated experimentally in a situation where the violation would give us good reason to reject local realism.

Robert Griffiths

Department of Physics, Carnegie-Mellon University
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Talk: Tuesday 17:15 – 18:30

Consistent Quantum Probabilities

By assuming that quantum dynamics is intrinsically stochastic rather than deterministic, and restricting probabilities to well-defined sample spaces, one can place quantum reasoning about microscopic as well as macroscopic systems on a sound footing, recover all the results of the textbook approach without invoking measurements, resolve the standard paradoxes, and get rid of the (supposed) nonlocalities which make many systems of quantum interpretation hard to reconcile with special relativity.

Carsten Held

Seminar für Philosophie, Universität Erfurt
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Talk: Tuesday 09:45 – 10:30

Quantum Measurement and No-Hidden-Variable-Proofs

There is a conflict between quantum mechanics (QM) and the usual expression for QM's completeness. In the standard axiomatization, the state of a QM system' S does not specify any of its properties (values), but only probabilities for values to be found on measurement. One can plausibly assume that if the state predicts a value a with certainty at some t, then S has value a at t. Completeness now standardly is expressed as the claim that beyond these values S possesses no values (COMP). COMP entails that quantum measurement cannot, in general, be faithful, i.e. reveal pre-existing values. COMP is assumed as proven in no-hidden-variables theorems (a corollary from Gleason's theorem and Kochen-Specker type results) that operate under two constraints on values ((i, value relations mirror operator relations) and (ii, values are noncontextual)). But one can show that COMP is inconsistent with QM plus two very plausible principles (P1 and P2). These principles indeed force a more precise axiomatization of QM, which makes explicit that QM measurement must be faithful. As a consequence, the no-hidden-variables results cannot be interpreted as expressing COMP. It cannot be false to assign pre-existing values, but rather it must be false to do so under constraints (i) and (ii). Of course, the burden of proof lies with principles P1 and P2. As these are discussed broadly elsewhere (arXiv:0705.2763), I here address the result's implications for QM measurement.

Klaus Hornberger

Arnold Sommerfeld Center for Theoretical Physics, Ludwig-Maximilians-Universität München
Klaus.Hornberger@physik.uni-muenchen.de

Talk: Monday 17:00 – 17:45

Decoherence and the boundaries of the quantum world

I will address the quantum-classical transition from the down-to-earth perspective of a theoretician involved in the microscopic description of macroscopic quantum interference.

Claus Kiefer

Institut für Theoretische Physik, Universität Köln
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Talk: Wednesday 11:00 – 11:45

Quantum gravity and the probability interpretation of quantum mechanics

The probability interpretation is at the heart of quantum mechanics. Its validity is connected with the presence of an external time. Models of quantum gravity, on the other hand, are fundamentally timeless. I shall argue that the probability interpretation does not make sense at this level. I shall then discuss in some detail to which extent the notions of time and probability can emerge from quantum gravity in appropriate situations.

Holger Lyre

Institut für Philosophie, Friedrich-Wilhelm-Universität Bonn
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Talk: Wednesday 11:45 – 12:30

Realism, Scientific Realism and Quantum Interpretations

Quantum theory is generally viewed as a threat to realism. Realism, however, is a philosophical doctrine with many faces and its own complexities. In my talk I will focus on the crucial difference between common sense realism and scientific realism. Loosely speaking, while the former confirms to reality in toto, the latter only concerns theoretical entities in our mature sciences. Scientific anti-realists may thus very well be (and usually are) common sense realists. I will try to analyse whether and in which sense quantum theory in its most prominent interpretations conflicts with either one or both of the two doctrines. Structural realism, a recently flourishing version of scientific realism, will also be considered. The analysis aims to illuminate in which sense quantum theory poses unique problems within the context of the realism debate.

Theo Nieuwenhuizen

Institute for Theoretical Physics, Amsterdam University
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Talk: Monday 17:45 – 18:30

Physical model for simultaneous measuring of non-commuting variables

A Hamiltonian model is presented for the quantum mechanical description of a measurement process. To measure the z-component of a spin $1/2$, it is coupled to an apparatus consisting of an Ising magnet (many spins $1/2$) and a harmonic bath. The apparatus starts in a mixed state: the magnet as a metastable paramagnet and the bath in a Gibbs state.

The small quantum signal of the spin is amplified because the apparatus goes to its stable up- or down ferromagnetic phase.

The exact solution of the problem explains two dogma's of textbooks:

- decay of Schrödinger cat terms on a very short but finite timescale;
- emergence of probabilities in the registration process (derivation of the Born rule).

The approach gives support for the statistical interpretation of QM.

With two such apparati one can simultaneously measure two components of the spin; this measurement cannot be sharp.

Maximilian Schlosshauer

School of Physics, University of Melbourne
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Talk: Monday 14:45 – 15:30

The nature of quantum states and collapse: Interpretations, decoherence, and classical concepts

What does the current landscape of interpretations of quantum mechanics look like with respect to assumptions about the nature of quantum states and of wave-function collapse? What role does environmental entanglement (decoherence) play in helping us explain seemingly fundamental elements such as measurement, quantum events, and classical concepts? In this talk, I will first give an overview of possible answers one may give to these questions, and then argue for the viability and merits of a "wave function only" approach to quantum mechanics. The main purpose of this talk is to outline the "big picture" and thus to lay out the playing field for further, more specialized discussion.

Harald Weinfurter

Sektion Physik, Ludwig-Maximilians-Universität München
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Talk: Tuesday 11:00 – 11:45

Loophole free Beel tests?

We describe plans for a Bell type experiment trying to close detection and locality loophole at the same time. The question arises, whether this is enough to disprove local hiddenvariable theories?

Reinhard Werner

Institut für Mathematische Physik, TU Braunschweig
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Talk: Wednesday 14:30 – 15:15

Layers of interpretation: what should we teach?

Quantum theory is often described as at the same time rife with paradox and immensely successful. I believe that we owe our students an explanation how the theory works pragmatically, and what one should know in order to contribute to that success story. But we should also encourage students to take their sense of paradox seriously, even if it mostly comes from naive extrapolation of classical intuitions. We should emphasize that classical notions are always possible, but at a price. The best we can do is to spell out this price as clearly as possible.

Apart from raising these points, I will comment on some of the talks and discussions of the workshop, taking a subjective view, and possibly arriving at some sort of conclusion.

Anton Zeilinger

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Talk: Monday 14:00 – 14:45

Information and Quantum Information and the Foundations of Physics

Hosts: Working group "Frontiers of Quantum Theory"

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Further useful information

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From Tegel Airport with the 109 bus (in the direction of Zoologischer Garten) to Jakob-Kaiser-Platz. There, transfer to the subway line 7 (U7 in the direction of Rudow) to Fehrbelliner Platz. There, transfer to the subway line 3 (U3 in the direction of Krumme Lanke) to Thielplatz, leave the station in driving-direction using the left exit, the Harnack-House is located app. 50 meters to your right.
From Airport Berlin Schönefeld with Bus 171 to underground-station Rudow. Here switch to U7 direction Rathaus Spandau. Get off at Fehrbelliner Platz and switch trains to U3 direction Krumme Lanke. Get off at Thielplatz, leave the station in driving-direction using the left exit, the Harnack-House is located app. 50 meters to your right.
From Mainstation/ Lehrter Bahnhof with S7 direction Potsdam until Zoologischer Garten. Take subway line 9 direction Rathaus Steglitz to Spichernstraße. Get off at Spichernstraße and switch trains to U3 direction Krumme Lanke. Get off at Thielplatz, leave the station in driving-direction using the left exit, the Harnack-House is located app. 50 meters to your right.
From Bahnhof Südkreuz (only selected trains) with S41 to Heidelberger Platz. Take subway line 3 direction Krumme Lanke to Thielplatz, leave the station in driving-direction using the left exit, the Harnack-House is located app. 50 meters to your right.
By car with the Autobahn 115 to the Hüttenweg offramp, turn right and go in the direction of Dahlem to the corner of Clayallee, right again, then turn left into Saargemünder Strasse and shortly thereafter is the Ihnestrasse. The Harnack-House is on the corner of Ihnestrasse and Saargmünder Strasse.

Conference dinner: we meet on Tuesday evening at **19h15** at the Harnack Haus entrance and then walk over to the Italian restaurant

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