SYRP 1: The Concept of Reality in Physics I

Time: Wednesday 14:30–16:00 Location: HSZ 01

Invited Talk SYRP 1.1 Wed 14:30 HSZ 01

What is realism in physics? What is the price for maintaining it? — •Anthony J. Leggett — Department of Physics, University of Illinois, Urbana, IL, USA

While the formalism of quantum mechanics, if taken seriously, appears to raise doubts about "naive realism" as applied to the physical world, a more important point (as appreciated in effect by the late John Bell) is that if in certain types of experiments the results come out as predicted by QM, then irrespective of the validity or not of the QM world view, *the experimental outcomes themselves* pose challenges to a realistic viewpoint. The relevant experiments fall into two major classes, each motivated by a classic paradox of QM:EPR on the one hand, Schrödinger's cat on the other. I will try to explore the possible meanings of "realism" in each of these contexts, and ask what price one has to pay (or may in the future have to pay, if the predictions of QM continue to be confirmed) in order to maintain some form of the concept of realism in physics.

Invited Talk SYRP 1.2 Wed 15:00 HSZ 01

Testing concepts of reality with entangled photons in the laboratory and outside — •Anton Zeilinger — Faculty of Physics, University of Vienna, Austria

In this talk, I will present some recent experiments on the foundations of quantum mechanics and discuss their implications. In tests of Bell's Inequalities over a distance of 144 km on the Canary Islands, we recently closed the Freedom of Choice Loophole[1]. There also have been new tests of quantum reality, realizing Schrödinger's idea of *steering* Wheeler's Delayed Choice, and Nonlocal Quantum Erasers. These, together with the experiments testing Leggett's Non-Local Realistic Model, hint that it is Naïve Realism which is at stake. Yet, in the talk I will also discuss other possibilities like counterfactual definiteness, retroaction, or determinism. Future fundamental experiments will certainly explore states in higher-dimensional regions of Hilbert space hitherto unexplored. Such experiments are possible with photons by employing for example modes beyond Gaussians like orbital angular momentum states and Hermite-Gaussian modes or multimode states using multiport beam splitters. A specific example is the question of mutually unbiased bases in an Hilbert space of dimension d.

[1] Proc. Natl. Acad. Sci. USA **46**, 19709-19713 (2010)

Invited Talk SYRP 1.3 Wed 15:30 HSZ 01

Special relativity and quantum entanglement: How compatible are they? — •Tim Maudlin — Department of Philosophy, Rutgers University, New Brunswick, NJ, USA

It is the entanglement of quantum systems–not issues concerning either determinism or uncertainty–that marks the strongest break between classical and quantum physics. The tension between entanglement and Relativity was the source of both Einstein's and Schrödinger's dissatisfaction with the standard understanding of quantum theory, on account of the ”magical” or ”spooky” effect that the measurement of one system was claimed to have on the physical condition of a distant entangled system. Bell proved that this non-locality of standard quantum theory is not eliminable: any theory capable of reproducing the standard predictions must be non-local. The import of Bell's work has even today not been universally appreciated. A full reconciliation between quantum theory and Relativity requires an exact formulation of quantum theory–including ”measurement”–that makes use only of Relativistic space-time structure. The non-locality cannot be eliminated, but perhaps it can be made completely Lorentz covariant. It is worth considering whether such a full reconciliation is possible, and, if so, whether it is worth the price.