Speaker: **Prof. Thomas Dittrich**

Titel: **Quantum randomness in spin measurement: a unitary approach**

Place: **Seminar room (915)**

Abstract:

Entanglement and nonlocality, two constituent features of quantum mechanics, have been demonstrated and amply confirmed in laboratory realizations of the Einstein-Podolsky-Rosen gedankenexperiment, honoured by the 2022 Nobel prizes. We here focus on a third, closely related emblematic phenomenon, also manifest in EPR-measurements: quantum randomness. In common interpretation, it stands out as an irreducible fundamental trait, incompatible with the canonical framework of unitary time evolution. We explore an alternative hypothesis, that it has an identifiable origin in the interaction of measurement apparatus and environment with the observed system and thus can be reconciled with unitary quantum mechanics.

We propose a simplified model for spin measurements (single arms of EPR setups) that takes the combined degrees of freedom of apparatus and environment as a finite heat bath explicitly into account. We thus avoid treating them collectively in a statistical framework, as in customary models of decoherence in quantum measurement. In numerical experiments, we simulate the unitary time evolution of the entire system, subject to a time-dependent modulation of the self-energy of the spin and the coupling to the heat bath. The long-time behaviour of the spin is registered as the outcome of the measurement. The expected quantum randomness, manifest in the final state, is observed in our simulations as a tendency of the spin to approach either one of the two eigenstates of the measured spin operator. The unitary approach allows us to trace these random outcomes individually and reproducibly back to fluctuations of the initial conditions of the apparatus and to demonstrate the two-way exchange of information between the two subsystems in the time evolution of their mutual entropy. The exclusive alternative of spin up vs. spin down, though, postulated by quantum measurement theory, is replaced by a continuous bimodal distribution that includes intermediate values or even undetermined outcomes with small but non-vanishing probability. Perspectives of our work are indicated, such as refining our model and an extending it towards complete EPR setups with two arms.