Seminar: Evidence of Dual Shapiro Steps in a Josephson Junction Array

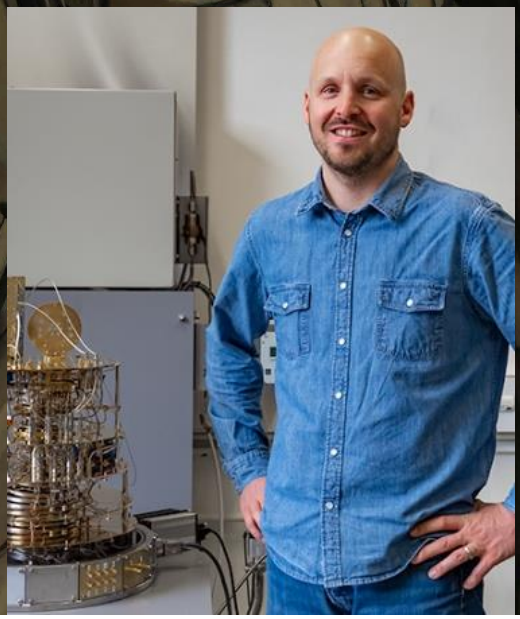
Nicolas Roch (Institut Néel, France)

Friday, 17 October 2025 @ 15:00-16h00 SAST

P213 Physics Building, Wits, and online

Abstract:
The modern primary voltage standard is based on the AC Josephson effect and the resulting Shapiro steps. When a microwave tone is applied to a Josephson junction, it produces a constant voltage of hf/2e (where h is Planck's constant and e is the electron charge), which is determined solely by the microwave frequency f and fundamental constants. Theoretical arguments regarding current and voltage have long suggested the existence of dual Shapiro steps—indicating that a Josephson junction device could generate current steps with heights determined only by the applied frequency. In this presentation, I will introduce an experimental platform featuring an ultrasmall Josephson junction embedded in a high-impedance array of larger junctions. Using the latest generation of these devices, we reveal the presence of dual Shapiro steps. For multiple frequencies, we observe that the AC response of the circuit is synchronized with the microwave tone at frequency f. This synchronization leads to the emergence of flat steps in the DC response with a current of 2ef, which corresponds to the tunneling of a Cooper pair for each tone period. This research sheds new light on phase-charge duality—a concept widely applicable in condensed matter physics—and extends it to Josephson circuits. Looking ahead, it opens up a wide range of possibilities for new experiments in the field of circuit quantum electrodynamics and represents a significant step toward resolving the long-anticipated closure of the quantum metrology electrical triangle.

Speaker:
Nicolas Roch is a permanent CNRS researcher at Institut Néel in Grenoble, where he leads work in the Quantum Electronic Circuits Alpes (QuantECA). He specializes in superconducting quantum circuits - especially superconducting qubits, parametric amplifiers and Josephson meta-materials - that aim to operate near the quantum limit of noise. Roch is also co-founder of SilentWaves, a start-up commercializing ultralow-noise microwave amplifiers. His research includes the ERC-funded **SuperProtected** project, which seeks to engineer superconducting qubits intrinsically protected from decoherence via novel encoding and nano-fabrication. In 2023, he was awarded the CNRS Bronze Medal for his contributions to fundamental quantum electronics.



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MITP Mandelstam Institute for Theoretical Physics

SA QuTI South African Quantum Technology Initiative

NITheCS National Institute for Theoretical and Computational Sciences