Research Proposal for Visit to Okinawa Institute of Science and Technology Graduate University (OIST)

Proposed Research Visit Duration: November 2025 – March 2026

Applicant: Karl Svozil

Institute for Theoretical Physics, TU Wien,
Wiedner Hauptstrasse 8-10/136, 1040 Vienna, Austria
August 20, 2024

1. Background and Current Research

My research has primarily focused on the foundational aspects of quantum mechanics, particularly in exploring quantum contextuality, nonlocality, and the development of quantum random number generators. My work addresses fundamental questions in quantum theory and explores the boundaries between classical and quantum physics, contributing to both theoretical insights and practical applications.

One of my recent studies, *"Converting nonlocality into contextuality"* (Physical Review A, 2024), presents a novel approach to understanding how quantum nonlocality can manifest as contextuality, providing new insights into the interplay between these two critical phenomena in quantum mechanics. Additionally, my co-authored work, *"Binary quantum random number generator based on value indefinite observables"* (Scientific Reports, 2024), develops a method for generating quantum randomness using value-indefinite observables, which has implications for quantum cryptography and computation.

Furthering my exploration into the quantum realm, my paper *"Form of contextuality predicting probabilistic equivalence between two sets of three mutually noncommuting observables"* (Physical Review A, 2024) delves into the probabilistic structures underlying quantum contextuality, offering predictions that can be empirically tested.

These research efforts have been complemented by a broader inquiry into the philosophical and mathematical foundations of quantum mechanics, as demonstrated in my works *"On the Complete Description Of Entangled Systems"* (International Journal of Theoretical Physics, 2024) and *"(Re)Construction of Quantum Space-Time"* (Entropy, 2024). These papers explore the limits of hidden variable theories and the conceptual underpinnings of quantum space-time, respectively.

I am also very interested in various interdisciplinary topics, including *"The Emergence of Cognition and Computation: A Physicalistic Perspective"*, as well as *"Quantum Music, Quantum Arts and Their Perception"*.

2. Proposed Research at OIST

During my visit to OIST, I intend to extend my research on quantum contextuality and nonlocality, with a particular focus on experimental implementations and potential technological applications. My goal is to collaborate with units at OIST that can provide both

theoretical and experimental support, particularly in the areas of quantum information science, quantum technologies, and mathematical physics.

Research Objectives

- **Exploration of Quantum Contextuality and Nonlocality:** I aim to investigate new forms of quantum contextuality that could lead to advancements in quantum communication protocols. This research will involve theoretical modeling and potential experimental collaborations to verify these models.
- **Development of Quantum Randomness Generation Techniques:** Building on my previous work, I plan to explore more efficient and secure quantum random number generators, particularly those based on value indefinite observables. This work has significant implications for cryptography and quantum computing.
- **Foundations of Quantum Mechanics and Quantum Gravity:** I am interested in exploring the intersection of quantum mechanics with gravitational theory, particularly in the context of quantum space-time constructions. This will involve both theoretical development and interaction with experimentalists working on quantum gravity experiments.

Proposed Research Units for Collaboration (excerpts)

- **Quantum Information Science and Technology Unit (Kae Nemoto)**
- **Quantum Systems Unit (Thomas Busch)**
- **Mathematical and Theoretical Physics Unit (Shinobu Hikami)**
- **Qubits and Spacetime Unit (Philipp Höhn)**
- **Quantum Gravity Unit (Yasha Neiman)**
- **Experimental Quantum Information Physics (Hiroki Takahashi)**

3. Expected Outcomes

The research conducted during my visit to OIST is expected to result in significant advancements in the understanding of quantum contextuality and its practical applications in quantum information science. I anticipate publishing joint papers with OIST researchers and contributing to the development of new quantum technologies. Moreover, the interdisciplinary nature of OIST will provide a fertile ground for generating novel ideas at the interface of quantum mechanics, information theory, and mathematical physics.

I am excited about the prospect of collaborating with OIST's world-class researchers and contributing to the institute's vibrant research community.

4. Title and abstract for general-audience talks

- **Quantum music and the human perception of quantum art (eg. this year's talk in Düsseldorf/Germany)**
- **Quantum randomness through quantum contextuality**
- **Varieties of quantum contextuality**
- **Quantum logic – A brief outline**