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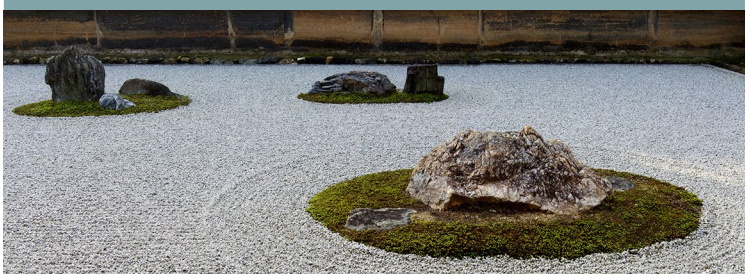
In the news

STRINGS AND QUBITS



Credit: Peter Elvin/Alamy Stock Photo

In June almost 300 researchers attended the Quantum Information and String Theory 5-week programme at the Yukawa Institute for Theoretical Physics, Kyoto University, Japan. The long workshop included topics of current interest in quantum information theory, such as the verification of quantum computing or quantum supremacy, and in string theory, for example, the holographic principle. Two weeks were dedicated to the 'It from qubit' school and workshop, an annual event of the Simons Foundation Program on Quantum Fields, Gravity and Information. The aim of the meeting was to bring together researchers from different fields. There were "a lot of exciting discussions among participants on how space-time emerges from quantum information," says Tadashi Takayanagi, one of the co-chairs of the meeting.

At first sight quantum information and string theory seem unrelated fields, but they are deeply connected through the anti-de Sitter/conformal field theory (AdS/CFT) correspondence, also known as the gauge/gravity duality. This correspondence, introduced by Juan Maldacena two decades ago, relates the theory describing quantum gravity to the quantum field theories used in particle physics. Using the gauge/gravity duality it is possible to calculate the entanglement entropy (which is a measure of entanglement, developed in quantum information theory) in quantum field theory as a geometric quantity. This led researchers to suspect that gravity might be a manifestation of the entanglement dynamics in quantum many-body systems; in other words, the gravitational universe may emerge from quantum information, a connection often dubbed it from qubit.

The links between the two fields go both ways: progress in quantum field theories led to better ways of analysing entanglement entropy. Tensor networks, originally developed in condensed matter physics and revived and expanded in quantum information theory, may explain how the anti-de Sitter space emerges from conformal field theories. Quantum error-correcting codes are essential for implementing reliable quantum computation. But in terms of the gauge/gravity correspondence, the relationship between quantum gravity and field theories can be regarded as a version of quantum error-correcting codes. There are also emerging links between quantum computational complexity theory and gauge/gravity correspondence.

The interface between quantum information and string theory is full of open questions and tantalizing possibilities. "Quantum information theory still has plenty of useful tools that are new to the string theory community, and string theory brings us new inspiration," says Tomoyuki Morimae, co-chair of the meeting. A major challenge in string theory is to understand the fundamental mechanism of gauge/gravity duality so it can be generalized to more realistic examples, such as de Sitter spaces. The ideas from quantum information theory may provide "very important clues to attack this important basic problem of why does AdS/CFT work," adds Takayanagi.

A related long-term programme on gravitational holography will take place early next year at the Kavli Institute for Theoretical Physics, University of California Santa Barbara, USA.

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