

It from Qubit

Simons Collaboration on Quantum Fields, Gravity, and Information

GOALS

Developments over the past ten years have shown that major advances in our understanding of quantum gravity, quantum field theory, and other aspects of fundamental physics can be achieved by bringing to bear insights and techniques from quantum information theory. Nonetheless, fundamental physics and quantum information theory remain distinct disciplines and communities, separated by significant barriers to communication and collaboration. Funded by a grant from the [Simons Foundation](#), *It from Qubit* is a large-scale effort by some of the leading researchers in both communities to foster communication, education, and collaboration between them, thereby advancing both fields and ultimately solving some of the deepest problems in physics. The overarching scientific questions motivating the Collaboration include:

- Does spacetime emerge from entanglement?
- Do black holes have interiors? Does the universe exist outside our horizon?
- What is the information-theoretic structure of quantum field theories?
- Can quantum computers simulate all physical phenomena?
- How does quantum information flow in time?

MEMBERSHIP

It from Qubit is led by 16 Principal Investigators from 15 institutions in 6 countries:

- [Patrick Hayden](#), Director (Stanford University)
- [Matthew Headrick](#), Deputy Director (Brandeis University)
- [Scott Aaronson](#) (MIT)
- [Dorit Aharonov](#) (Hebrew University)
- [Vijay Balasubramanian](#) (University of Pennsylvania)
- [Horacio Casini](#) (Bariloche Atomic Centre)
- [Juan Maldacena](#) (Institute for Advanced Study)
- [Alex Maloney](#) (McGill University)
- [Donald Marolf](#) (University of California, Santa Barbara)
- [Robert Myers](#) (Perimeter Institute)
- [Jonathan Oppenheim](#) (University College London)

- [Joseph Polchinski](#) (Kavli Institute for Theoretical Physics)
- [John Preskill](#) (Caltech)
- [Leonard Susskind](#) (Stanford University)
- [Tadashi Takayanagi](#) (Kyoto University)
- [Mark Van Raamsdonk](#) (University of British Columbia)

It also currently involves 5 postdoctoral fellows:

- Henry Maxfield (McGill University)
- Fernando Pastawski (Caltech)
- Douglas Stanford (Institute for Advanced Study)
- Brian Swingle (Stanford University)
- Beni Yoshida (Perimeter Institute)

PROJECTS

These members, along with graduate students and outside scientists, collaborate on a variety of projects at the interface of fundamental physics and quantum information theory. There are currently 8 projects underway (PI participants are listed after each project):

1. Using tensor networks to reconstruct bulk geometry from boundary states
Aharanov, Balasubramanian, Hayden, Maloney, Marolf, Myers, Polchinski, Susskind, Takayanagi
2. AdS/CFT and quantum error correction
Balasubramanian, Casini, Hayden, Maldacena, Myers, Polchinski, Preskill, Susskind, Van Raamsdonk
3. Chaos and the black hole horizon
Maldacena, Maloney, Oppenheim, Polchinski, Susskind
4. Operational interpretation of entanglement entropy in gauge field theories
Casini, Hayden, Headrick, Oppenheim, Preskill
5. Constraints on gravitational spacetimes from entanglement inequalities
Headrick, Maloney, Marolf, Myers, Takayanagi, Van Raamsdonk
6. Building models of theories with information destruction
Oppenheim, Polchinski, Preskill
7. Multipartite entanglement in quantum field theory and gravity
Balasubramanian, Headrick, Maloney, Marolf, Susskind

- 8. Circuit complexity and the validity of general relativity at late times
- Aaronson, Balasubramanian, Hayden, Maloney, Marolf, Susskind

The projects being pursued will evolve according to developments in the field. In addition, *It from Qubit* supports research by individuals and small groups on a variety of other topics related to its scientific goals.

MORE INFORMATION

More information on the scientific background and goals, organization, and activities of *It from Qubit* may be found at <http://web.stanford.edu/~phayden/simons/simons-proposal.pdf>.