Joe Polchinski's Restless Pursuit of Quantum Gravity

Grand ideas have a way of turning up in unusual settings, far from an office or a chalkboard. Months ago, Quanta Magazine set out to photograph some of the world's most accomplished scientists and mathematicians in their favorite places to think, tinker and create. This series explores the role of cherished spaces — public or private, spare or crowded, inside or out — in clearing a path to inspiration.

By Natalie Wolchover and Olena Shmahalo and Lucy Reading-Ikkanda

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Joe Polchinski at the Kavli Institute for Theoretical Physics in Santa Barbara, California.

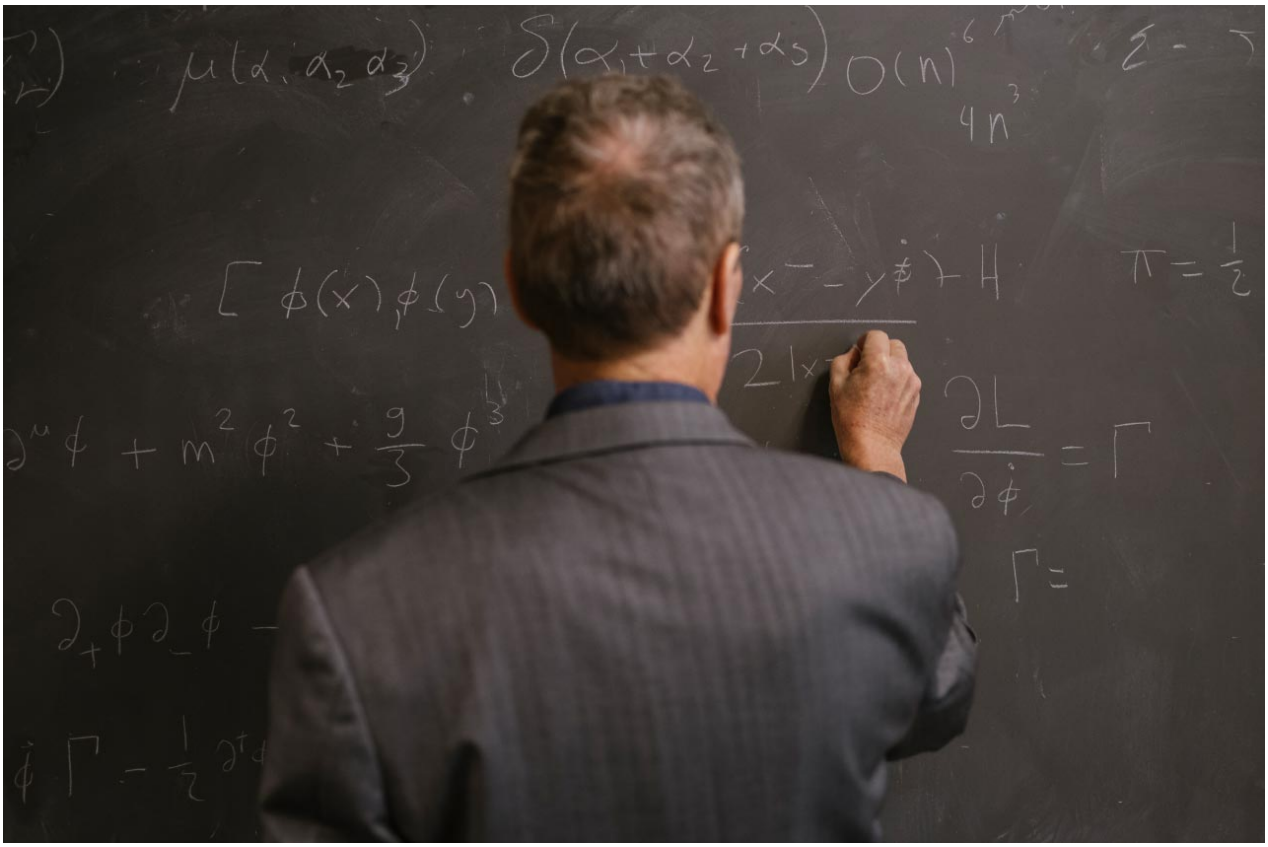
Joe Polchinski, who won the 2017 Breakthrough Prize in Fundamental Physics "for transformative

advances in quantum field theory, string theory and quantum gravity," can't sit still.

"I am fidgety," he told *Quanta* in an email. "I will calculate in my chair for a while, then switch to the blackboard, then go for a walk inside the building." Then he'll find somewhere quiet to sit among the "many excellent spaces" at the Kavli Institute for Theoretical Physics (KITP) at the University of California, Santa Barbara, where he has worked for 25 years. Then, he said, "perhaps a walk along the cliffs over the ocean."

Polchinski literally wrote the book on string theory (he authored the seminal 1998 textbook *String Theory*). The "second superstring revolution" of the mid- to late 1990s resulted in part from an epiphany he had in October 1995. "I think it happened in my office or — possibly — on the way to the men's room," he said.

The sudden realization concerned D-branes — certain one-dimensional strings, two-dimensional membranes and higher-dimensional objects that, according to his work, undulate in 10 space-time dimensions and help shape the universe's properties. "The key feature about D-branes is that they carry a certain charge that nothing else carries; this followed from a combination of two papers I had written several years earlier," Polchinski explained. The discovery meant that D-branes were essential components of string theory, predicted by the mathematical dualities that tie different versions of the theory together. D-branes added a rich new mathematical structure to the theory and allowed researchers to construct cosmological models that treated the three-dimensional fabric of the universe as a giant D-brane.



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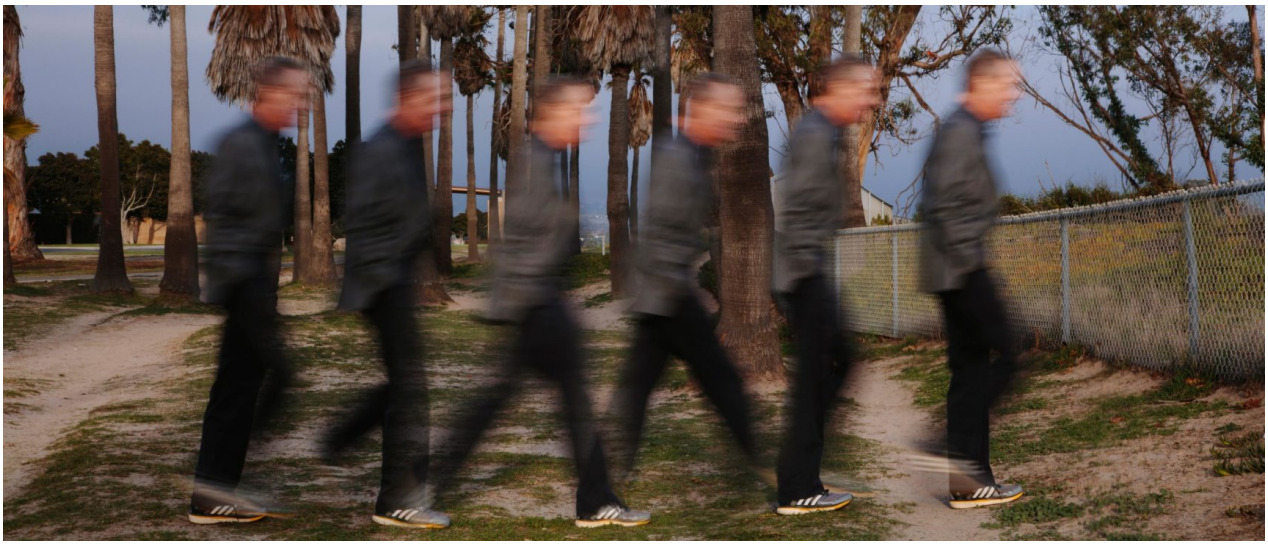
In the early 2000s, Polchinski and Raphael Bousso, now at the University of California, Berkeley, ushered in another, more anguished chapter in string theory history. By calculating that the theory allows a dizzying "landscape" of some 10^{500} different solutions, they dashed hopes that the properties of our universe could be explained as inevitable, unique consequences of an underlying fundamental theory.

Polchinski stirred the pot again in 2012 by discovering a paradox about the nature of black holes. The "firewall argument," as it's called — developed with Ahmed Almheiri, Donald Marolf and James Sully — "took form over three months and involved many discussions, in offices and seminar areas all around the KITP building," he said.



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"The first thing to know is that the two great theories of physics (quantum mechanics and general relativity) work very well in most circumstances, but in extremes like the beginning of the Big Bang we do not know how to fit them together," Polchinski said. "Black holes are a great testing ground for this. The firewall paradox seems to say that one of the two theories must be modified, and that the result is that the black hole interior is replaced by a wall of quantum bits." It's a dramatic and — to some — distasteful conclusion, yet theorists have a hard time seeing their way around black hole firewalls.

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Polchinski, 63, was diagnosed with brain cancer in late 2015. “I have been writing my autobiography while I recover,” he said. “I continue to think about the firewall and other questions.”