



## Exploring the origin of freely adjustable parameters in the fundamental equations of nature

Study offers new clues to the mystery of free parameters in quantum gravity

**Fukuoka, Japan**—A researcher at Kyushu University and his collaborators have shown that continuous parameters in quantum gravity may not be freely adjustable “dials” from outside the theory, but rather arise from operators within the theory itself, supporting the century-old claim by Albert Einstein about the fundamental laws of nature.

Einstein argued that the fundamental equations of physics contain no freely adjustable parameters. In other words, he believed that the laws of nature should not include arbitrary numbers chosen from outside a theory. Instead, such quantities should emerge naturally from physical processes.

This idea has become especially important in the search for quantum gravity, a theory that aims to combine gravity with quantum mechanics. Physicists expect that the equations governing quantum gravity should not contain freely adjustable quantities. Rather, all parameters should arise from physical fields.

To validate this idea, physicists often turn to conformal field theory (CFT), a framework describing systems whose behavior remains essentially unchanged across different length scales.

In some CFTs, exactly marginal operators are those that slowly tune the theory without disturbing its conformal properties. This creates a smooth family of related theories called a conformal manifold, thereby leading to an interesting question: If a conformal manifold exists, does it imply the presence of exactly marginal operators? Proving this would suggest that continuous parameters in quantum gravity are not freely chosen but instead correspond to operators already present within the theory itself.

An international research team comprising Associate Professor [Yuya Kusuki](#) at Kyushu University’s [Institute for Advanced Study](#), Dr. Shota Komatsu from CERN, Dr. Marco Meineri from the University of Turin, and Professor Hiroshi Ooguri from the California Institute of Technology, has now answered this question under certain assumptions.

Their study will be published in the journal [Physical Review Letters](#) on June 16, 2026.

“A key challenge in modern physics is understanding whether the laws of nature contain freely adjustable numbers from outside the theory or whether such quantities arise from the theory itself. Our work shows that continuous changes in a theory can be generated by local operators within the theory,” explains Kusuki.

The researchers approached the problem through CFT and then used the anti-de Sitter

(AdS)/CFT correspondence, which relates CFTs to theories of quantum gravity in AdS space, to understand what the result could imply for quantum gravity.

The team made several assumptions. First, they assumed that for any two closely related CFTs on a conformal manifold, there exists a conformal interface, a mathematical boundary separating the two theories, which becomes trivial when the theories are identical. Second, they assumed that certain correlation functions remain smooth as the interface disappears.

Under these assumptions, the researchers showed that an exactly marginal operator can be reconstructed directly from the interface's displacement operator, which describes how the interface responds to slight shifts.

"By studying how this interface responds when it is displaced slightly, we constructed an operator that generates changes in the parameter. In this way, we identified the origin of what had appeared to be a freely adjustable quantity," says Kusuki.

The findings suggest that, under certain assumptions, continuous parameters in CFT arise from local operators within the theory itself. "Through the AdS/CFT correspondence, these results support the prediction that 'there are no freely chosen external parameters' in quantum gravity and are expected to lead to a better understanding of fundamental problems in quantum gravity," explains Kusuki.

The team notes that their finding currently applies only to two-dimensional CFTs. In the future, they hope to investigate whether the same concept applies to more general cases of CFT.

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For more information about this research, see "Continuous Family of Conformal Field Theories and Exactly Marginal Operators," Shota Komatsu, Yuya Kusuki, Marco Meineri, and Hiroshi Ooguri, *Physical Review Letters*, <https://doi.org/10.1103/4759-7qj2>

### **About Kyushu University**

Founded in 1911, [Kyushu University](#) is one of Japan's leading research-oriented institutions of higher education, consistently ranking as one of the top ten Japanese universities in the Times Higher Education World University Rankings and the QS World Rankings. Located in Fukuoka, on the island of Kyushu—the most southwestern of Japan's four main islands—Kyushu U sits in a coastal metropolis frequently ranked among the world's most livable cities and historically known as Japan's gateway to Asia. Its multiple campuses are home to around 19,000 students and 8,000 faculty and staff. Through its [VISION 2030](#), Kyushu U will "drive social change with integrative knowledge." By fusing the spectrum of knowledge, from the humanities and arts to engineering and medical sciences, Kyushu U will strengthen its research in the key areas of decarbonization, medicine and health, and environment and food, to tackle society's most pressing issues.

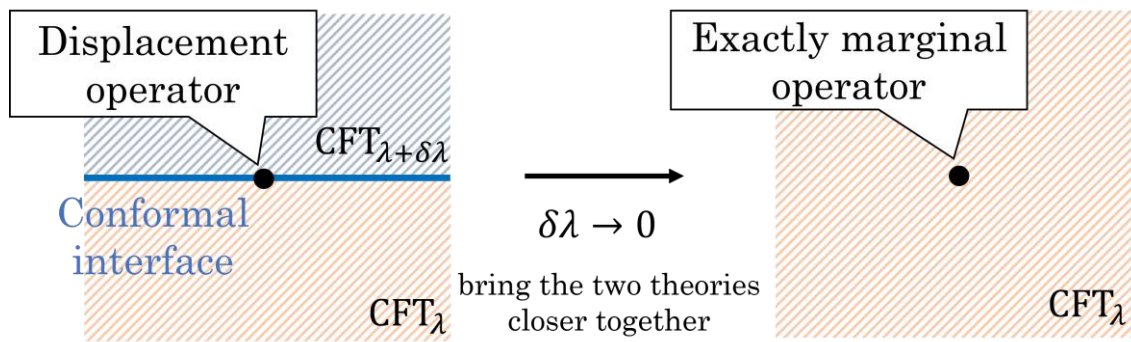


Fig. 1. Conceptual illustration of extracting theory-deforming operators from the response of an interface

Two nearby conformal field theories are connected by a *conformal interface*. We showed that, as the two CFTs are brought closer and closer to coincide, an exactly marginal operator can be constructed from the displacement operator.

[Contact]

Mitsuru Tanaka, Associate Professor

Faculty of Agriculture

Tel: +81 92 802 4753

E-mail: mitsurut@agr.kyushu-u.ac.jp