The quantum theory of gravitation, effective field theories and strings: Past and present

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Gravity is one of four fundamental interactions. The most precise description of this force is still provided by Einstein's General Theory of Relativity, published in 1915, an entirely classical theory. This description sets gravity apart from the other three forces—strong, weak, and electromagnetism—all described by quantum fields. Therefore, any attempt to unify the four forces must depend on a description of gravity

that uses the principles of quantum mechanics.

This has been an active area of theoretical physics since the 1930s. A historian and a physicist, Alessio Rocci from VUB in Brussels and Thomas Van Riet from KU Leuven in Belgium have set out a historical overview of the development of quantum theories of gravity to explain our current view on a future unified theory of the four forces. This work has been published in *The European Physical Journal H*.

Physicists began to investigate the quantum theory of gravitation in the 1930s, taking a perturbative approach, convinced that there should be no fundamental difference between the gravitational force and the other interactions. However, finding a description of the gravitational interaction according to the laws of quantum mechanics is still a very complex task.

Later in the century, Steven Weinberg, a pioneer of both effective field theory and the standard model of particle physics, began a process of cross-fertilization between these areas and the research area of quantum gravity that produced our current view on Einstein's theory. From the mid-1980s, string theory set up a possible framework to approach quantum gravity using a 'top-down' approach. The effective field theory approach to strong forces drove the development of the 'bottom-up' perspective, culminating in the mid-1990s.

Recently, physicists have started a new program called Swampland to overcome the criticism of string theory that arose in the 2000s. Van Riet says, "The ultimate hope is that the Swampland program can lead to general patterns with observational consequences."

More information: Alessio Rocci et al, The quantum theory of

gravitation, effective field theories, and strings: yesterday and today, *The European Physical Journal H* (2024). DOI: 10.1140/epjh/s13129-024-00069-4