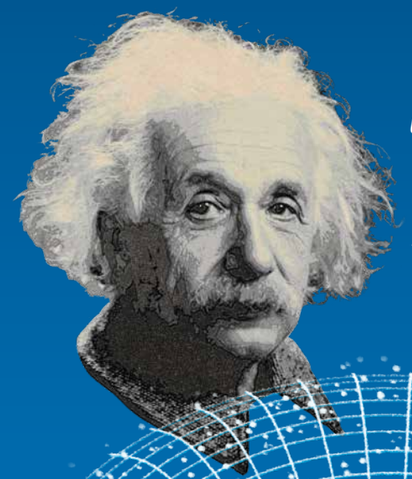
On the shoulders of giants

From the very small to the very large, whether it is the unpredictable behaviour of particles or the heart of a black hole, physics seeks to make sense of all of nature. Great minds such as Albert Einstein, Stephen Hawking, and Richard Feynman paved the way. Delta ITP researchers are now trying to discover what outlooks this path offers, continuing to pioneer where the route ends, and noting what unusual things they encounter along the way.

TEXT: ANS HEKKENBERG
ILLUSTRATIONS: PASCAL TIEMAN

SPACETIME



'Einstein enabled us to understand that space and time are full of life. They can curve, expand, vibrate'

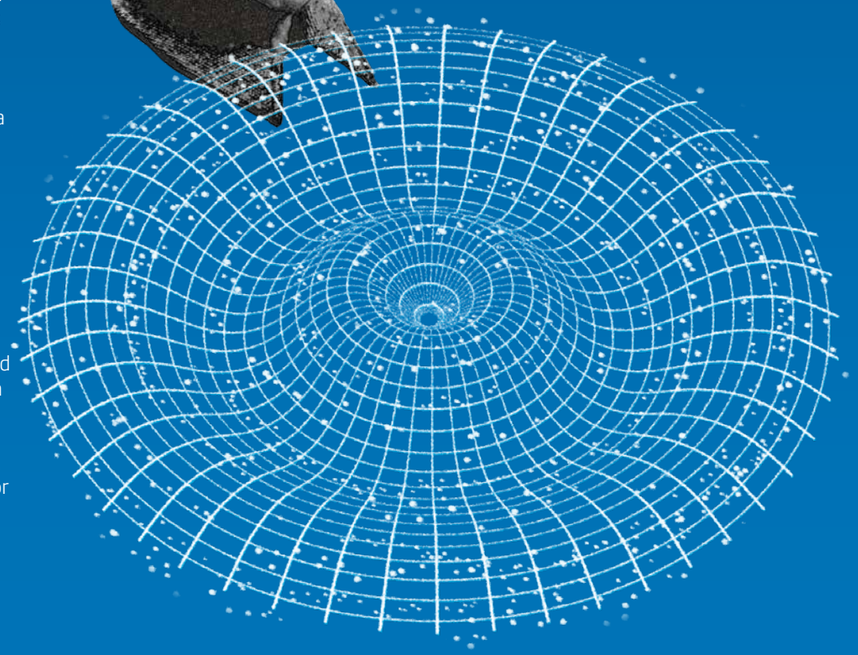
– Robbert Dijkgraaf, string theorist and Minister of Education, Culture, and Science

When Albert Einstein took the stage, it seemed that physicists already had a pretty good grasp of gravity. It is the force by which masses attract each other. For example, a black hole attracts nearby stars, the sun attracts the earth, and the earth attracts people who do not go floating off into space as a result.

But knowing how something works is not the same as knowing why it works that way. Einstein took the theory of gravity a major step further by asking himself that question. He realised that a mass curves the spacetime around it. And everything that moves through space must conform to that curve.

As a result, a star near a black hole inevitably falls in: the star follows the prescribed path of curved spacetime around this dark monster. The earth, in turn, spins around in the curved spacetime of the sun.

Spacetime that can be warped opened up a new chapter in cosmology. Einstein realised that space could also vibrate when two black holes collide – a phenomenon he called gravitational waves. In 2015, these waves were measured for the first time, exactly 100 years after Einstein predicted them.



'Hawking bridged the – ever mysterious – gap between quantum mechanics and Einstein's spacetime'

– string theorist Jan de Boer, University of Amsterdam

THE EDGE OF REALITY

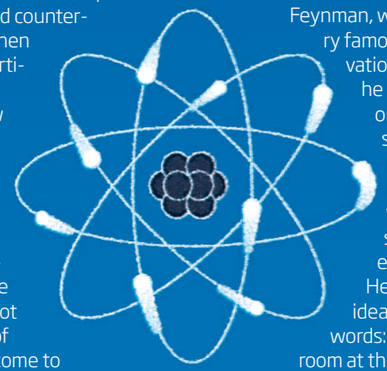
What happens when you slip over the edge of a black hole? You will be lost forever, that much is clear. Even light cannot escape the extreme curvature surrounding these cosmic heavyweights. But does that also mean that black holes emit nothing but deafening silence? Or can we still pick up a signal from these exciting regions of spacetime? Stephen Hawking asked this question and came upon the greatest insight of his career. Suppose you are looking at the edge of a black hole – exactly at the point that makes the difference between being swallowed up and escaping. There, Hawking reasoned, a particle and an antiparticle can be formed. One of the two can be swallowed, while the other can just barely escape. We should be able to detect the escaping particles as so-called Hawking radiation. So far, this remains a theoretical prediction; Hawking radiation has never been measured. But the search is in full swing. Hawking radiation brings us closer to a message from the underbelly of a black hole than will ever be possible in any other way.

'Feynman connected the fundamental physics of the very smallest with groundbreaking applications'

– Rembert Duine, professor of nanophysics at Utrecht University

MASTERING THE PARTICLE WORLD

From the largest to the smallest: the world of particles is one of uncertainties. For example, a particle can be in two places at once. Or it can spin both clockwise and counterclockwise. Only when you look at the particle (i.e., measure where it is, or how it spins) does it end up in one of the possibe states. Because of this fundamental uncertainty, the world at the smallest scale is not one of facts, but of probabilities. Welcome to the uncertain realm of quantum mechanics.



The path to the smallest was explored by physicists such as Werner Heisenberg, Erwin Schrödinger, and Paul Dirac. A new formulation of quantum mechanics came from the mind of the American theoretical physicist Richard Feynman, who made the theory famous with his observation that he thought he could 'safely say no one really understands quantum mechanics'. Feynman saw that the world of the very small offers unprecedented possibilities. He immortalised that idea with the winged words: 'There is plenty of room at the bottom.' By building with atoms, manipulating particles, and gaining control of quantum laws, physicists hope to master the world down to its deepest foundation.