

Einstein's theory describes how everything and everyone in the universe is held in the grip of gravitation. Gravity holds us on Earth, it governs the orbits of the planets around the Sun and the orbit of the Sun around the centre of the Milky Way. It leads to the birth of stars from interstellar clouds, and eventually their death in a gravitational collapse. Gravitation brings shape to space and influences the passage of time. A heavy mass bends space and slows time; an extremely heavy mass can even cut off and encapsulate a piece of space – forming a black hole.

The first theoretical description of what we now call a black hole came just a few weeks after the publication of the general theory of relativity. Despite the theory's extremely complicated mathematical equations, the German astrophysicist Karl Schwarzschild was able to provide Einstein with a solution that described how heavy masses can bend space and time.

Later studies showed that once a black hole has formed, it is surrounded by an event horizon that sweeps around the mass at its centre like a veil. The black hole remains forever hidden inside its event horizon. The greater the mass, the larger the black hole and its horizon. For a mass equivalent to the Sun, the event horizon has a diameter of almost three kilometres and, for a mass like that of the Earth, its diameter is just nine millimetres.

A solution beyond perfection

The concept of the 'black hole' has found new meaning in many forms of cultural expression but, for physicists, black holes are the natural end point of the evolution of giant stars. The first calculation of the dramatic collapse of a massive star was made at the end of the 1930s, by physicist Robert Oppenheimer, who later led the Manhattan Project that constructed the first atomic bomb. When giant stars, many times heavier than the Sun, run out of fuel, they first explode as supernovas and then collapse into extremely densely packed remnants, so heavy that gravity pulls everything inside, even light.

The idea of 'dark stars' was considered as long ago as the end of the 18th century, in the works of the British philosopher and mathematician John Michell and the renowned French scientist Pierre Simon de Laplace. Both had reasoned that heavenly bodies could become so dense that they would be invisible – not even the speed of light would be fast enough to escape their gravity.

A little more than a century later, when Albert Einstein published his general theory of relativity, some of the solutions to the theory's notoriously difficult equations described just such dark stars. Up until the 1960s, these solutions were regarded as purely theoretical speculations, describing ideal situations in which stars and their black holes were perfectly round and symmetrical. But nothing in the universe is perfect, and Roger Penrose was the first to successfully find a realistic solution for all collapsing matter, with its dints, dimples and natural imperfections.

The mystery of quasars

The question of the existence of black holes resurfaced in 1963, with the discovery of quasars, the brightest objects in the universe. For almost a decade, astronomers had been puzzled by radio rays from mysterious sources, such as 3C273 in the constellation of Virgo. The radiation in visible light finally revealed its true location – 3C273 is so far away that the rays travel towards Earth for over a billion years.

If the light source is such a long way away, it must have an intensity equal to the light of several hundred galaxies. It was given the name 'quasar'. Astronomers soon found quasars that were so distant they had emitted their radiation in the early childhood of the universe. Where does this incredible radiation come from? There is only one way to obtain that much energy within the limited volume of a quasar – from matter falling into a massive black hole.