



Black holes and the Milky Way's darkest secret

Three Laureates share this year's Nobel Prize in Physics for their discoveries about one of the most exotic phenomena in the universe, the black hole. Roger Penrose showed that the general theory of relativity leads to the formation of black holes. Reinhard Genzel and Andrea Ghez discovered that an invisible and extremely heavy object governs the orbits of stars at the centre of our galaxy, the Milky Way. A supermassive black hole is the only currently known explanation.

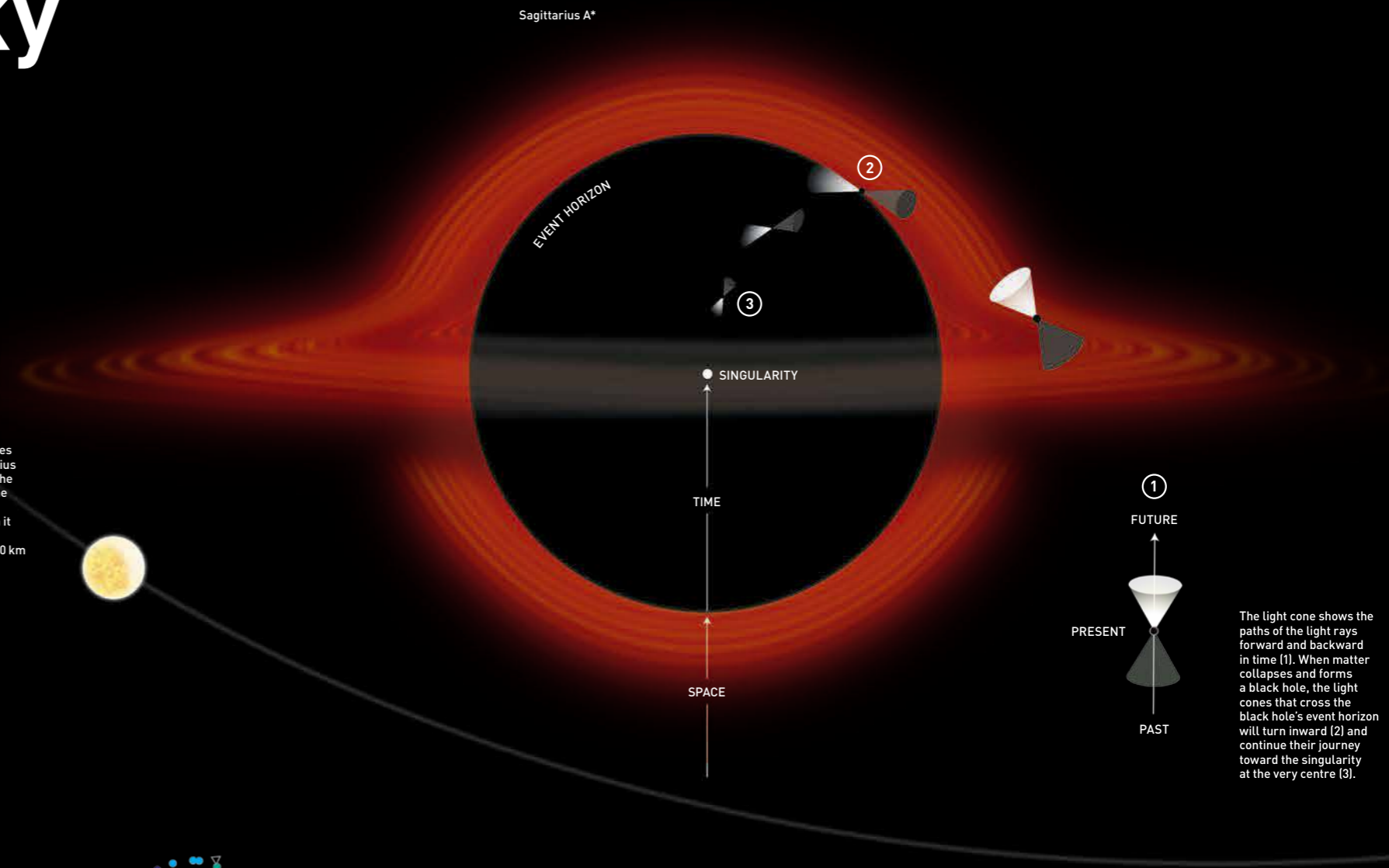
Roger Penrose used ingenious mathematical methods in his exploration of Albert Einstein's general theory of relativity. This theory describes how gravity bends a four-dimensional spacetime and is the foundation for all modern research about the universe. When a huge mass is squeezed together in a tiny volume, matter collapses and forms a black hole, a monster of spacetime that captures everything that enters it. Nothing, not even light, can escape.

Albert Einstein did not believe that black holes could exist but, in January 1965, ten years after Einstein's death, Penrose demonstrated that black holes can form and described them in detail. The centre of every black hole hides a singularity, where all known laws of nature cease to apply. His revolutionary article is still regarded as the most important contribution to the general theory of relativity since Einstein.

Reinhard Genzel and **Andrea Ghez** each lead separate groups of astronomers that have focused on an area called Sagittarius A*, at the heart of our galaxy, since the early 1990s. With increasing precision, they have mapped the orbits of the brightest stars that are closest to the centre. Both research groups found something that is both invisible and heavy, forcing this jumble of stars to swirl around at incredible speeds. About four million solar masses are squeezed together in a region no larger than our solar system.

Their pioneering work has led the way for new generations of precise tests of the general theory of relativity and its most intriguing predictions. Most likely, these measurements will also be able to provide clues for new theoretical insights. The universe has many secrets and surprises left to be discovered.

The star S2 completes one orbit of Sagittarius A* every 16 years. The closest it came to the black hole was just 17 light hours, when it achieved its highest speed of around 7,600 km per second.

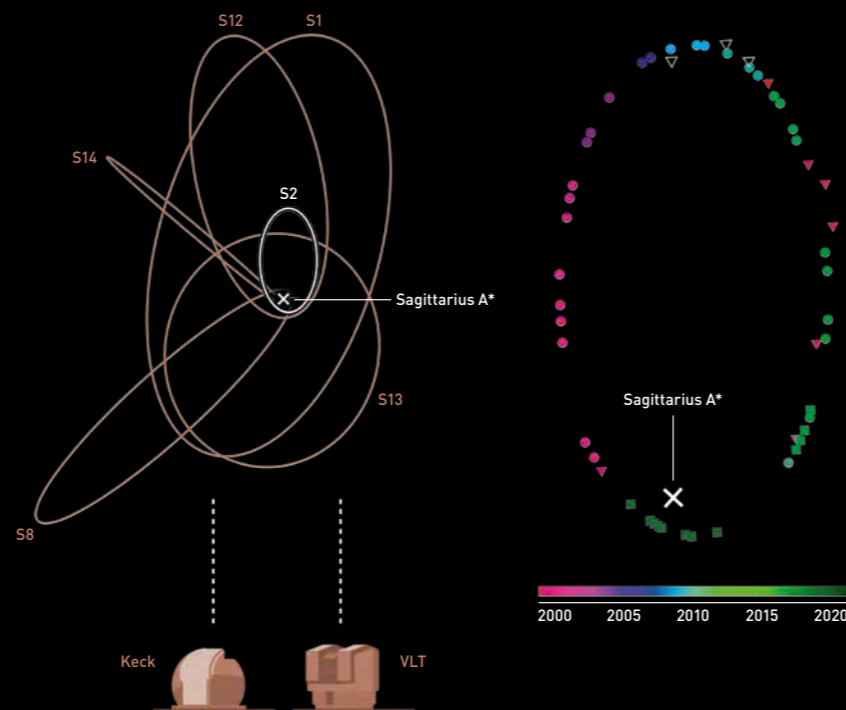


The light cone shows the paths of the light rays forward and backward in time (1). When matter collapses and forms a black hole, the light cones that cross the black hole's event horizon will turn inward (2) and continue their journey toward the singularity at the very centre (3).

Roger Penrose
Born 1931 in the UK. Professor at the University of Oxford, UK.

Reinhard Genzel
Born 1952 in Germany. Director at MPI for Extraterrestrial Physics, Germany and Professor at University of California, Berkeley, USA.

Andrea Ghez
Born 1965 in the USA. Professor at the University of California, Los Angeles, USA.



The paths of the stars reveal the black hole

For thirty years, Reinhard Genzel, Andrea Ghez and their research groups have mapped the stars' orbits around Sagittarius A*, a bright radio source at the centre of our galaxy, the Milky Way. To see through the Earth's atmosphere and the huge clouds of interstellar gas and dust, they developed new methods and built unique instruments at the world's largest telescopes – the VLT in Chile (Genzel's group) and the Keck Observatory in Hawaii (Ghez's group).

With more sensitive light sensors and better optics, image resolution has improved more than a thousandfold. The astronomers are thus able to more precisely determine the stars' positions, following them night by night.

The elliptical orbits of the stars reveal how they are affected by an invisible heavy object. This is the most convincing evidence yet that a supermassive black hole is hiding there.

A black hole

A black hole's gravity is so strong that it captures everything that crosses its boundary – the event horizon – and the black hole remains forever hidden inside its event horizon. The greater the mass, the larger the black hole. For a mass like that of the Earth, a black hole would be no larger than a pea.

At the event horizon, the arrow of time replaces one dimension of space and only points inwards. The flow of time carries everything towards a singularity inside the black hole, where density is infinite and time ends.

An intensely bright disc rotates around the black hole. It is made from hot gas and charged particles that the black hole is about to swallow. The rear of the disc is also visible from the front, because the strong gravity of the black hole distorts spacetime and deflects the light rays.

