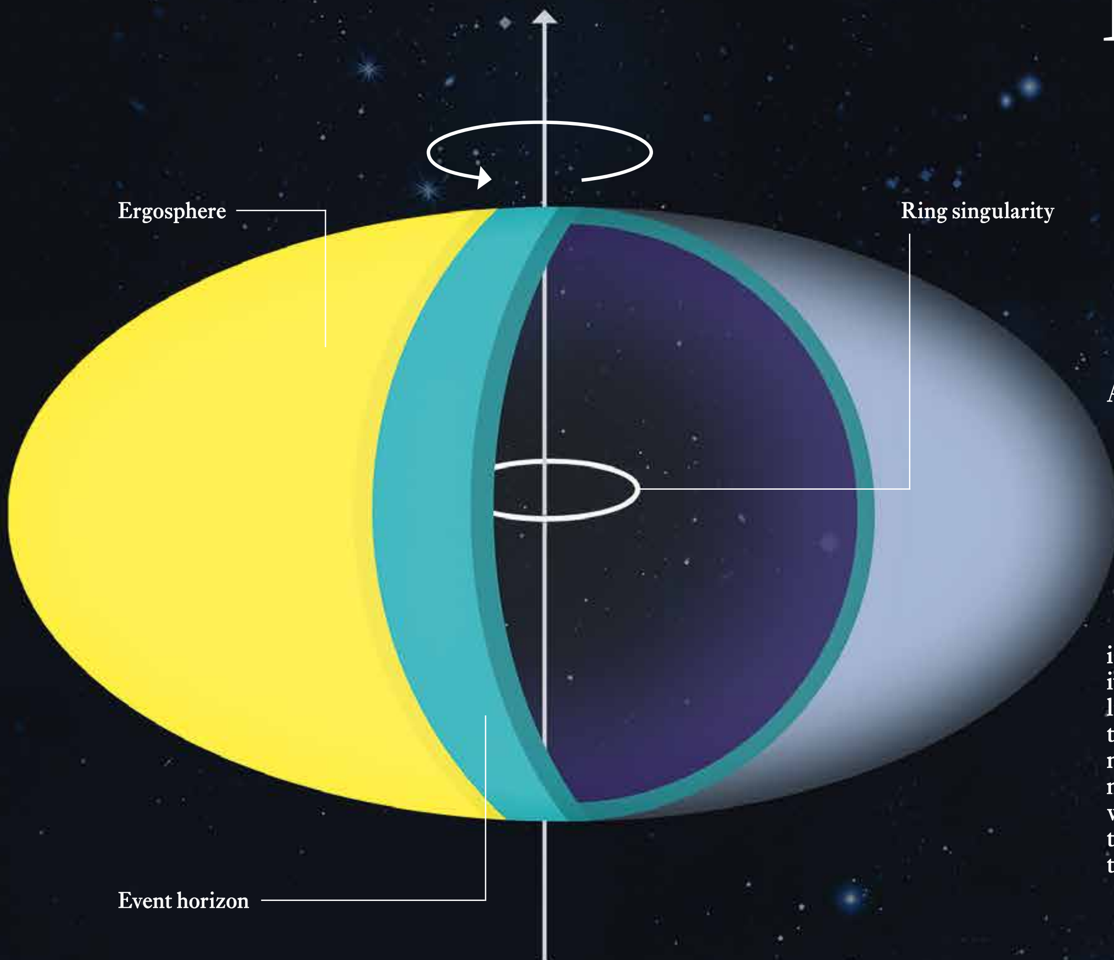
BLACK HOLES – SPACE-TIME TRAPS



Abstract mathematics is being used to determine the structural design of a rotating black hole. It is impossible to imagine a *ring singularity* with no spatial extension. Easier to envision is the *event horizon*; it defines the size and limit beyond which there is no return, neither for light nor matter. Everything within the *ergosphere* has to rotate in sync with the black hole.

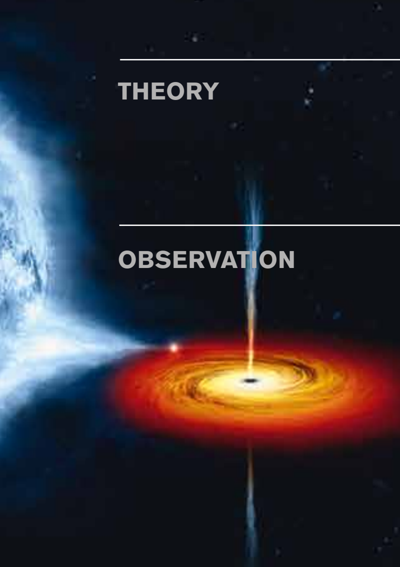
An incredible thought experiment: compress the Earth to the size of a cherry and you turn it into a black hole.

THEORY

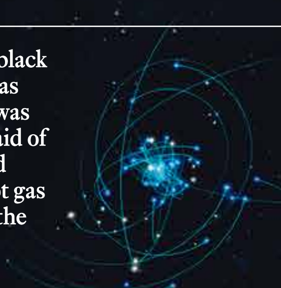
In 1783, John Michell first imagined “dark stars”, which do not emit light because of their gravitation.

In 1915, Albert Einstein created the mathematical basis for such objects in his general theory of relativity. A year later, Karl Schwarzschild described the geometry of a static black hole.

OBSERVATION



In the early 1970s, the first stellar black hole (Cygnus X-1) was discovered as part of a binary star system. This was accomplished indirectly with the aid of an X-ray satellite, which registered high-energy radiation from the hot gas disk (accretion disk) surrounding the black hole.

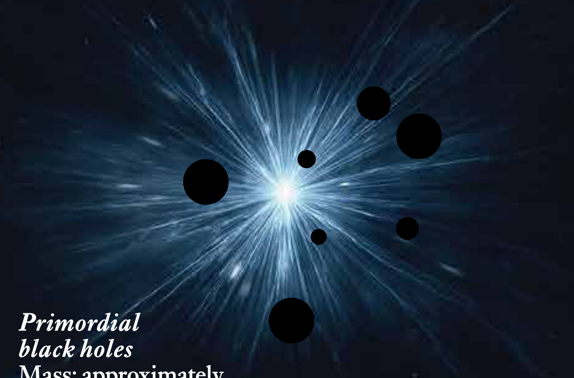


Groups led by Andrea Ghez (University of California, Los Angeles) and Reinhard Genzel (Max Planck Institute for Extraterrestrial Physics) had been observing the orbits of stars at the center of our Milky Way since the 1990s and concluded the existence of a black hole of 4.3 million solar masses, for which they received the 2020 Nobel Prize in Physics.

IMAGES GCO; ISTOCK; NASA/CXC/M. WEISS; ESO/L. CALÇADA/SPACEENGINE.ORG (FROM TOP TO BOTTOM)

VARIOUS TYPES

Four types of black holes can be differentiated according to their respective masses:



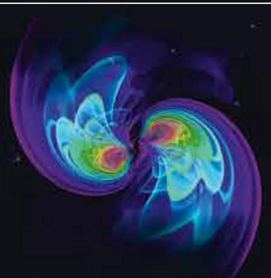
Primordial black holes
Mass: approximately equal to that of the Earth's moon
Origin: Big Bang

Stellar black holes
Mass: between 3 and 65 solar masses
Origin: Supernova (how heavier black holes of up to 120 solar masses are formed remains unclear)

Supermassive black holes
Mass: between a few million and billions of solar masses
Origin: mergers between numerous black holes, each comprising several hundred solar masses; collisions between galaxies or accretions of mass gathered from surrounding space

Moderately heavy black holes
Mass: between 120 and 100,000 solar masses
Origin: collisions between stellar black holes; mergers between massive stars or the Big Bang

In the 1960s, the theory of relativity experienced a renaissance as a result of new observations. Roger Penrose (2020 Nobel Prize in Physics) and Stephen Hawking demonstrated the presence of a singularity of infinite density, as well as an infinite curvature of spacetime within black holes.



The gravitational waves predicted by Einstein were detected for the first time on September 14th 2015 and emanated from the merger of two black holes having 29 and 36 solar masses, respectively.

Scientists published the first image of a black hole in 2019, which was pieced together from images taken by the Event Horizon Telescope – a network of eight radio observatories scattered over half the globe – and shows the massive monster at the heart of Galaxy M87.

IMAGES: ISTOCK; NASA, ESA, AND J. BANOVETZ AND D. MILISAVLJEVIC (PURDUE UNIVERSITY); ISTOCK; S. OSSOKINE, A. BUONANNO (MPI FOR GRAVITATIONAL PHYSICS); SIMULATING EXTREME SPACETIME PROJECT, D. STEINHAUSER (AIRBORNE HYDRO MAPPING GMBH); EHT COLLABORATION (TOP TO BOTTOM)