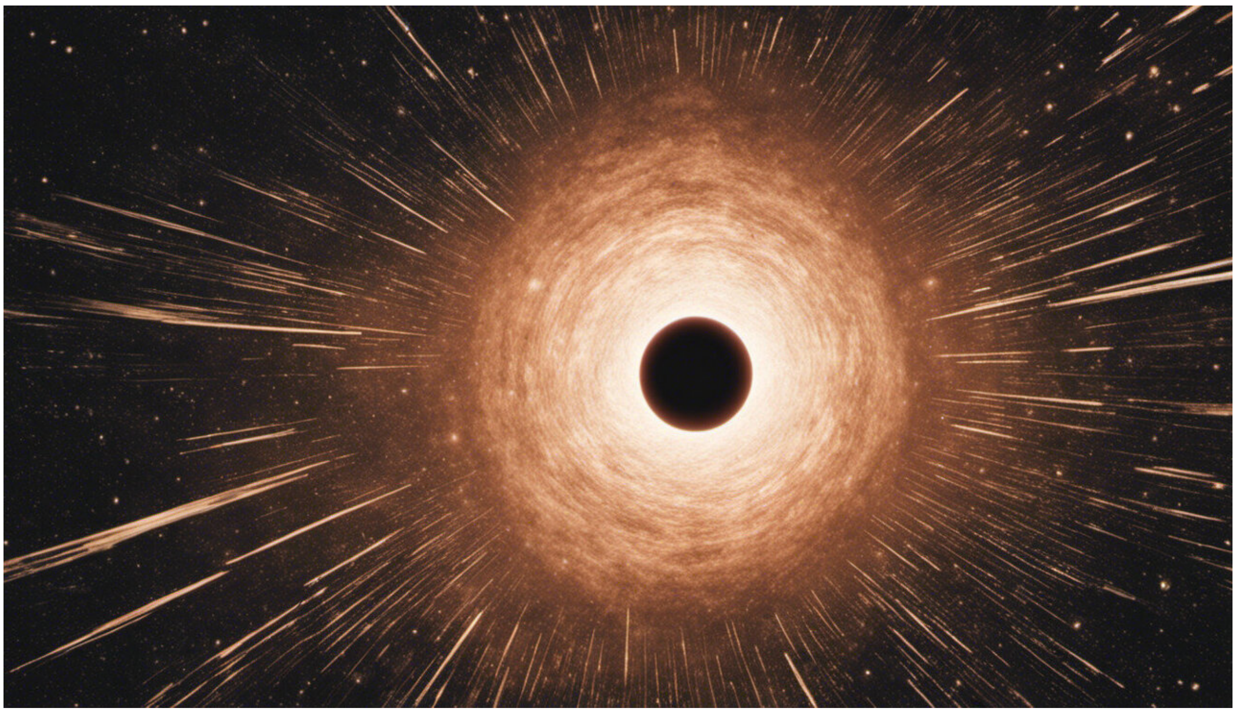
A brief history of black holes

December 28 2018, by Carla Rodrigues Almeida



Credit: AI-generated image (disclaimer)

Late in 2018, the gravitational wave observatory, LIGO, announced that they had detected the most distant and massive source of ripples of spacetime ever monitored: waves triggered by pairs of black holes colliding in deep space. Only since 2015 have we been able to observe these invisible astronomical bodies, which can be detected only by their gravitational attraction. The history of our hunt for these enigmatic objects traces back to the 18th century, but the crucial phase took place in a suitably dark period of human history – World War II.

The concept of a body that would trap light, thereby becoming invisible to the rest of the universe, had first been considered by the natural philosophers John Michell and later Pierre-Simon Laplace in the 18th century. They used Newton's gravitational laws to calculate the escape velocity of a light particle from a body, predicting the existence of stars so dense that light could not escape from them. Michell called them "dark stars".

But after the discovery that light took the form of a wave in 1801, it became unclear how light would be affected by the Newtonian gravitational field, so the idea of dark stars was dropped. It took roughly 115 years to understand how light in the form of a wave would behave under the influence of a gravitational field, with Albert Einstein's General Relativity Theory in 1915, and Karl Schwarzschild's solution to this problem a year later.

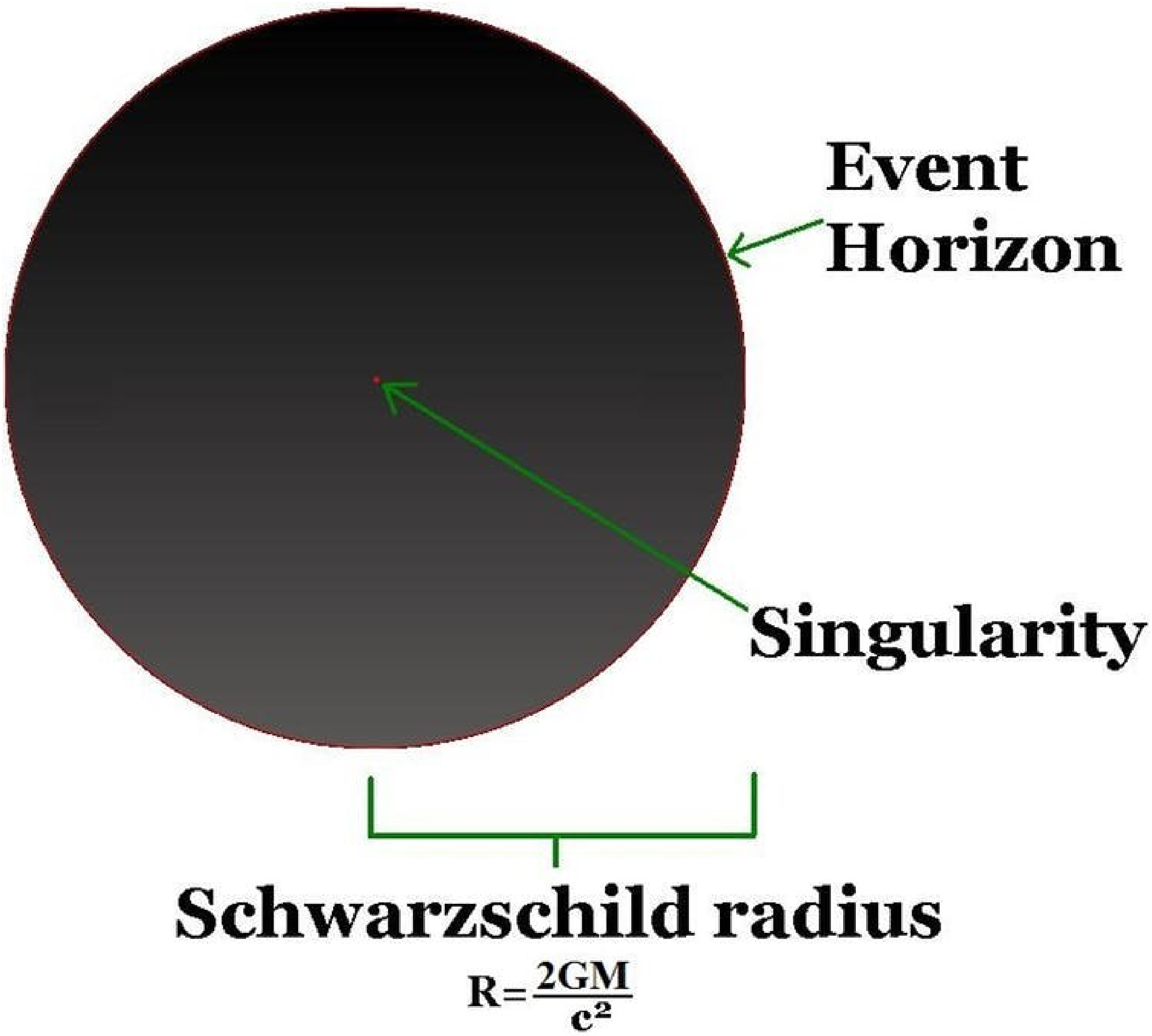
Schwarzschild also predicted the existence of a critical circumference of a body, beyond which light would be unable to cross: the Schwarzschild radius. This idea was similar to that of Michell, but now this critical circumference was understood as an impenetrable barrier.

It was only in 1933 that George Lemaître showed that this impenetrability was only an illusion that a distant observer would have. Using the now famous Alice and Bob illustration, the physicist hypothesised that if Bob stood still while Alice jumped into the black hole, Bob would see Alice's image slowing down until freezing just before reaching the Schwarzschild radius. Lemaître also showed that in reality, Alice crosses that barrier: Bob and Alice just experience the event differently.

Despite this theory, at the time there was no known object of such a size, nothing even close to a black hole. So nobody believed that something similar to the dark stars as hypothesised by Michell would exist. In fact, no one even dared to treat the possibility with seriousness. Not until World War II.

From dark stars to black holes

On September 1 1939, the Nazi German army invaded Poland, triggering the beginning of the war that changed the world's history forever. Remarkably, it was on this very same day that the first academic paper on black holes was published. The now acclaimed article, On Continued Gravitational Contraction, by J Robert Oppenheimer and Hartland Snyder, two American physicists, was a crucial point in the history of black holes. This timing seems particularly odd when you consider the centrality of the rest of World War II in the development of the theory of black holes.



The Schwarzchild radius. Credit: Tetra Quark/Wikimedia Commons, CC BY-SA

This was Oppenheimer's third and final paper in astrophysics. In it, he and Snyder predict the continued contraction of a star under the influence of its own gravitational field, creating a body with an intense attraction force that not even light could escape from it. This was the first version of the modern concept of a black hole, an astronomical body so massive that it can only be detected by its gravitational attraction

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In 1939, this was still an idea that was too strange to be believed. It would take two decades until the concept was developed enough that physicists would start to accept the consequences of the continued contraction described by Oppenheimer. And World War II itself had a crucial role in its development, because of the US government's investment in researching atomic bombs.

Reborn from the ashes

Oppenheimer, of course, was not only an important character in the history of black holes. He would later become the head of the Manhattan Project, the research centre that led to the development of atomic weapons.

Politicians understood the importance of investing in science in order to bring military advantage. Consequently, across the board, there was wide investment in war-related revolutionary physics research, nuclear physics and the development of new technologies. All sorts of physicists dedicated themselves to this kind of research, and as an immediate consequence, the fields of cosmology and astrophysics were mostly forgotten, including Oppenheimer's paper.

In spite of the decade lost to large-scale astronomical research, the discipline of physics thrived as a whole as a result of the war – in fact, military physics ended up augmenting astronomy. The US left the war as the centre of modern physics. The number of Ph.D.s skyrocketed, and a new tradition of postdoctoral education was set up.

By the end of the war, the study of the universe was rekindled. There was a renaissance in the once underestimated theory of general relativity. The war changed the way we do physics: and eventually, this led to the fields of cosmology and general relativity getting the recognition they deserve. And this was fundamental to the acceptance and understanding of the black holes.

Princeton University then became the centre of a new generation of relativists. It was there that the nuclear physicist, John A Wheeler, who later popularised the name "black hole", had his first contact with general relativity, and reanalysed Oppenheimer's work. Sceptical at first, the influence of close relativists, new advances in computational simulation and radio technology – developed during the war – turned him into the greatest enthusiast for Oppenheimer's prediction on the day that war broke out, September 1 1939.

Since then, new properties and types of black holes have been theorised and discovered, but all this only culminated in 2015. The measurement of the gravitational waves created in a black hole binary system was the first concrete proof that black holes exist.

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