

Speaker's manuscript – Physics Prize 2020

Black holes and the Milky Way's darkest secret

The Nobel Prize in Physics

- The Nobel Prize in Physics is one of the five prizes founded by Alfred Nobel and awarded on 10 December every year.
- Before Alfred Nobel died on 10 December, 1896, he wrote in his will that the largest part of his fortune should be placed in a fund. The yearly interest on this fund would pay for a prize given to "those who, during the preceding year, shall have conferred the greatest benefit to humankind."
- The interest would be divided into five equal parts, with one part awarded to those who "shall have made the most important discovery or invention within the field of physics".



Who is rewarded with the Physics Prize?

- This prize rewards important discoveries or inventions in the field of physics.
- Guglielmo Marconi and Karl Ferdinand Braun received the Physics Prize in 1909 for the development of radio ("wireless telegraphy"). Subramanyan Chandrasekhar received the 1983 prize for studying processes of importance to the structure and evolution of the stars. Pierre and Marie Curie for pioneering research on radiation, awarded 1903.



The 2020 Physics Prize

- The 2020 Physics Prize is about one of the strangest phenomena in the universe: black holes.
- One half of the prize is about theoretical predications about black holes. The other half is about the discovery of a giant black hole.



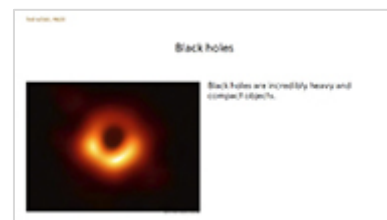
The 2020 Physics Laureates

- Half of the prize has been awarded to Roger Penrose for his theoretical work, which demonstrates that black holes are a direct consequence of Einstein's general theory of relativity.
- The other half of the prize has been awarded to Reinhard Genzel and Andrea Ghez, who have made pivotal contributions to the discovery of an invisible but incredibly heavy object at the centre of our galaxy, the Milky Way – an object that must be a black hole.



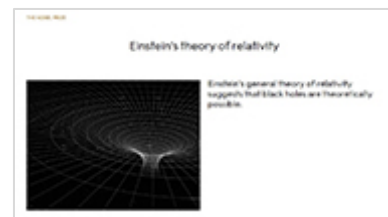
Black holes

- Black holes are incredibly heavy and compact objects. If the planet Earth was as compact as a black hole, it would be just 9 millimetres in diameter. The gravitational pull from a black hole is so powerful that nothing - not even light - can escape from it.
- The image is from 2019 and is the first to show a black hole.



Einstein's theory of relativity

- The idea of "dark stars" that are so heavy that even light cannot escape them has been around for over 200 years. When Albert Einstein formulated his general theory of relativity in 1915, it gave that idea new life.
- The theory of relativity contradicts our basic understanding of time and space. According to the theory, a heavy object bends space and slows down time, and an extremely heavy object can even cut off and enclose a piece of space. That's how a black hole is formed.
- In Einstein's day, however, these conclusions were regarded by many as just theoretical speculations that were not grounded in physical reality.



New mathematical tools for black holes

- Roger Penrose tried to answer the question of whether black holes could really be formed. In 1964 he proposed a pivotal mathematical tool called "trapped surfaces" to describe black holes.
- Penrose's mathematical methods demonstrated that the general theory of relativity does in fact lead to the formation of black holes.
- In a black hole, space and time are completely different from the way we perceive them here on earth. This picture is an attempt to illustrate a black hole. It is so heavy that it captures everything that passes through its so-called "event horizon" - not even light can escape. At the event horizon, time replaces space and points only forward. The flow of time carries everything and everyone towards a "singularity" at the very centre of the black hole, where density is infinite and time comes to an end.



Observing a black hole

- Black holes can only be observed through radiation and the movement of nearby objects.
- Since the 1990s, Reinhard Genzel and Andrea Ghez have been leading research teams that have developed and refined the technology used to study the movements of stars.
- The image shows the Keck Observatory in Hawaii, where Ghez and her co-workers have made some important observations.



Searching the galaxy

- For more than 50 years, physicists have suspected that there might be a black hole at the centre of the Milky Way. They found a powerful source of radio waves there that has been given the name of Sagittarius A*.
- Reinhard Genzel and Andrea Ghez have tracked the movements of about 30 stars in the area with the clearest view of starlight.



Star orbits provide evidence

- The researchers track the movements of about 30 of the brightest stars in the vicinity of Sagittarius A*. Closer to the centre of the galaxy the stars move faster, and farther out they have slower, more orderly movements.
- One of these stars, S2, makes a complete orbit around the galaxy's centre in just 16 years. That is record time, and short enough that astronomers have now been able to map out the path of the star's orbit. For comparison, it takes the sun and the planets more than 200 million years to make a complete loop around the centre of the Milky Way.
- The measurements taken by the two separate research teams agreed very closely with each other, leading to the conclusion that the black hole at the centre of our galaxy should be equivalent to around 4 million suns packed into an area the size of our solar system.



Expected surprises?

- It's hard to see any direct benefit of these discoveries about black holes, but they do stimulate our thinking and wondering about our vast universe and what secrets might be hiding out there.
- Black holes have given rise to some startling ideas, such as the "worm holes" that provide a kind of shortcut to other places in time and space.
- Physicists are also busy developing new theories that are related to black holes. Inside the black hole's singularity, the density is infinite, but there is no theory yet that can explain this fact. Can a new theory of quantum gravitation - one that brings together quantum physics and the theory of relativity - perhaps offer a path in the right direction?



“It amazes me every time I go to the telescope.”

- In an interview given in conjunction with the announcement of the 2020 Physics Prize, Andrea Ghez said that a passion for the universe is her strongest motivation. Although she has been doing research on space and black holes for a long time, she has never stopped being fascinated by what she sees in the telescope.

