KUNGL. VETENSKAPS-AKADEMIEN
THE ROYAL SWEDISH ACADEMY OF SCIENCES

# Theoretical foundation for black holes and the supermassive compact object at the Galactic centre

The Royal Swedish Academy of Sciences has decided to award the Nobel Prize in Physics 2020

with one half to

**Roger Penrose**

*for the discovery that black hole formation is a robust prediction of the general theory of relativity*

and the other half jointly to

**Reinhard Genzel** and **Andrea Ghez**

*for the discovery of a supermassive compact object at the centre of our galaxy*

## Introduction

This year's Nobel Prize in Physics focuses on black holes, which are among the most enigmatic objects in the Universe. The Prize is awarded for establishing that black holes can form within the theory of general relativity, as well as the discovery of a supermassive compact object, compatible with a black hole, at the centre of our galaxy.

## The early history

The first scientists to discuss the possibility of dark objects with an escape velocity larger than the speed of light were the English astronomer and priest John Michell, in 1783, and the French polymath Pierre-Simon Laplace, in works from 1796 and 1799.

In a contribution to *Philosophical Transactions of the Royal Society* (Michell 1783), Michell calculated that a star with the same density as the Sun, but a radius 500 times as large, would have a gravitational pull so strong that light would be trapped and unable to escape. In his *Exposition du Système du Monde* (Laplace 1796), Laplace made a similar suggestion, independently of Michell. He provided the full details in a mathematical treatise from 1799 (Laplace 1799), where he considered a star with the same density as Earth, i.e., four times the density of the Sun. He arrived at a radius 250 times that of the Sun.

The objects contemplated by Michell and Laplace would now be classified as supermassive black holes with masses between that of the compact object at the centre of our galaxy, the subject of this year's Nobel Prize, and the black hole candidate at the centre of M87, recently imaged by the Event Horizon Telescope (EHT).

The calculations of Michell and Laplace were made within the framework of Newtonian mechanics. The results are easily obtained by setting the total energy of a test particle equal to zero, so that it just barely can escape from the dark object. This gives $\frac{1}{2}mv^2 - \frac{GMm}{r} = 0$, from which it follows that a radius smaller than $\frac{2GM}{c^2}$ prevents a particle of light from reaching infinity. In his work from 1799, Laplace explicitly presented just this formula. In his work, Michell had