This year's Nobel Prize in Physics has been awarded for earlier work that indirectly established the existence of black holes. The English mathematical physicist Roger Penrose won half the prize for his 1965 paper showing that black hole formation is a robust prediction of the general theory of relativity, according to the Nobel committee.

Roger Penrose made his key contribution in 1965, not long after the discovery of superluminous objects called quasars. These objects were so bright that researchers hypothesized that they might be the gleam of material falling into ultra-compact, supermassive objects. This renewed interest in the decades-old question of whether black holes were just a mathematical artifact of Einstein's theory, or if they actually form in the universe.

Penrose showed that they can. In fact, he showed that they inevitably do.

Up until then, researchers had tied themselves in knots trying to figure out whether objects like the Schwarzschild solution of Einstein's equations — the simplest kind of black hole, worked out on paper by Karl Schwarzschild in 1916 — were really possible in nature. Such theoretical solutions had only been studied under the simplifying assumption that the material doing the gravitational collapsing is a perfect sphere. The question was whether the resulting singularity was simply an artifact of that perfect spherical symmetry — something possible on paper, but preposterous in nature.

Penrose showed that, as he put it in his 1965 paper, deviations from spherical symmetry cannot prevent space-time singularities from arising. In other words, even when a star is distorted, it will still collapse down to a point. He showed this by introducing the notion of a trapped surface, as well as a now-famous diagrammatic scheme for analyzing how the surface sits inside space-time. Unlike a regular surface, which can have light rays shooting away from it in any direction, a trapped surface is a closed two-dimensional surface that — even when distorted so it's no longer a sphere — only allows light rays to go one way: toward the center point.

Penrose found that the dimensions of space and time switch roles inside a trapped surface. Time is the direction pointing toward the center, so that escaping a black hole is as impossible as going back in time. Penrose, together with Stephen Hawking, soon showed that a similar analysis applies to the entire universe: A singularity would have inevitably existed when matter and energy were densely packed together in the Big Bang.