Roger Penrose, black holes, and the Nobel Prize

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Carla Rodrigues Almeida has recently joined the KWI as an International Research Fellow. With a master in Mathematics and a Ph.D. in Physics, Carla is currently researching the historical path of the discovery and acceptance of black holes, focusing on how the understanding and perception of those objects changed over the decades. During her time at the KWI, she will work on a proposal of a book on this topic.

The announcement of the laureates of the 2020's Nobel Prize of Physics was celebrated by the entire community of physicists and astronomers, and also by every woman in science. The Nobel committee is gradually acknowledging the impressive research by women in the field, and theoretical work on the cosmos and its constituents. This year the prize was dedicated to the most fascinating object out there: black holes.

Astronomer Andrea Ghez and astrophysicist Reinhard Genzel received the highest honor of Physics for their discovery of a super-dense object at the center of the Milky Way, a massive black hole which holds our galaxy together. They share the prize with Sir Roger Penrose, who in the sixties and seventies fundamentally contributed to the theoretical development of black-holes physics.

Black holes are among the most mysterious objects in the universe. A super-massive body so dense it drastically bends the space-time around itself: it creates an ineluctable gravitational pull in its interior and thereby closes itself off from the rest of the universe. In its interior lies a singularity; an infinitely dense point where the matter content of the black hole concentrates. It is hidden by a fictitious unidirectional membrane called "event horizon", which delimits the region of no-return. Once inside, there is no way out.

The first ever solution of Einstein's equation of general relativity comprises a black hole, although this conclusion was not obvious at the time. In the first quarter of the 20th century, both theory and observation pointedaway from the idea that there exist such objects in the skies. Skepticism persisted even after in the late thirties, theoretical predictions were settled that super massive stars would collapse under the influence of their own gravitational force, forming a black hole. An invisible region outside the scope of possible measurements, observable only through its gravitational power was much of a strange idea to believe.

Although theoretical input increased during the fifties, it was in the sixties that the first observational evidences appeared, and the quasar was singled out as a likely candidate for a black hole. Paired with successful computer simulation pointing towards the gravitational collapse, physicists cautiously accepted the plausibility of this phenomenon, the gravitational collapse of massive stars into black holes. By then, the theory about black holes was underdeveloped, and apart from their existence, little was understood. The gravitational collapse was predicted using a simplistic model of a perfectly spherical star. What would happen in the case of deformations? The singularity at the center of the region was another concern: can holes protrude the smooth fabric of space-time?

Enters Roger Penrose. In 1965 he published a paper on the gravitational collapse and singularities, assuring that deviations from spherical symmetry in stars would not prevent the collapse to happen and that the end-point would be a singularity at its center. Four years later together with late physicist Stephen Hawking he moreover proved that not only gravitational collapse due to super-massive stars but singularities in general are unavoidable according to the theory of general relativity. Penrose also observed that every singularity is hidden by at least one event horizon in a conjecture that became known as Cosmic Censorship.

At the inaugural conference of the European Physical Society in Florence in 1969, Penrose presented a thorough survey on the topic of gravitational collapse, in which he detailed the concept of black holes and their main properties, advocating for them to be taken seriously, and pleading for the community to search for one in space. Most notably, he also presented a new feature of the theory, a mechanism to extract rotational energy of a black hole which is today known as the “Penrose Process”. First proposed by Jacob Bekenstein, it was a crucial tool for the development of the thermodynamics of black holes in the following years and changed our perception of those objects. This culminated in Stephen Hawking’s conclusion that black holes should radiate, and that they in fact, may also evaporate.

In March 2019, the Event Horizon Telescope team released the first image of a black hole, once again confirming Einstein’s theory of gravitation, general relativity. Penrose’s plea was finally answered, and wefound a black hole in space using the theory he had laid for us. Earlier this year, in June 2020, Marion Cromb and collaborators claimed to have proven the Penrose Process via an analogue experiment proposed by Soviet Academician Yakov Zeldovich in 1970, further establishing the theory.

Penrose is undeniably one of the greatest names in the history of the discovery of black holes, and now his name is forever recognized among the greats of the field, deservedly so. We can only wonder about the outcome of the prize if Stephen Hawking were still alive. Considering his and Penrose’s partnership, and his equally amazing contributions to the field, it is a fair guess that they would have shared this prize like Ghez and Genzel.

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