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The global information and cosmological problem: 2020 Nobel Prize winner in Physics Roger Penrose

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Abstract: The paper presents brief biographical information and an overview of the research work of Roger Penrose, the 2020 Nobel Prize winner in Physics. The scientific research of this British scientist is at the epicenter of modern cosmology, which solves particularly complex problems in astrophysics and physical systems.

Keywords: Nobel Prize in Physics 2020; Roger Penrose; cosmology; astrophysics; complex physical systems.

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Глобальная информационно-космологическая проблема: лауреат Нобелевской премии по физике 2020 года Роджер Пенроуз

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Аннотация: Представлены краткие биографические сведения и обзор научной деятельности лауреата Нобелевской премии по физике за 2020 г. Роджера Пенроуза. Научные исследования этого британского ученого находятся в эпицентре современной космологии, решающей особо сложные задачи в области астрофизики и сложных физических систем.

Ключевые слова: Нобелевская премия по физике 2020 г.; Роджер Пенроуз; космология; астрофизика; сложные физические системы.

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Continuing the series of articles on Nobel laureates [1, 2], this one discusses Roger Penrose, the 2020 Nobel Prize winner in Physics. The press release from the Royal Swedish Academy of Sciences (KShAN), which awards the Nobel Prize in Physics, mentioned three laureates who shared this award in

Fig. 1. Roger Penrose and his Nobel diploma (© Nobel Foundation)

2020 (10 million SEK) *"*for their discoveries about one of the most exotic phenomena in the universe, the black hole*"*. "Roger Penrose showed that the general theory of relativity leads to the formation of black holes. Reinhard Genzel and Andrea Ghez discovered that an invisible and extremely heavy object governs the orbits of stars at the centre of our galaxy. A super massive black hole is the only currently known explanation" [ibid.]. The prize amount was 10 million Swedish kronor, with one half to Roger Penrose (Fig. 1) "for the discovery that the formation of black holes is reliably predicted by general relativity", and the other half jointly to Reinhard Genzel and Andrea Ghez "for the discovery of a super massive compact object at the center of our galaxy" [ibid].

The discovery of the quasar 3C273 (an extragalactic source with spectral lines indicating its location outside the Milky Way) in 1963 by the Dutch astronomer M. Schmidt prompted J.A. Wheeler to reconsider the physics of gravitational collapse, and he discussed this with R. Penrose, who began to think about this problem at the end of 1964. Earlier, R. Oppenheimer and H. Snyder described a spherically symmetric case when an astronomical body is compressed, forming a singularity of infinite density. Whether this could happen in the real world, and whether the assumption of spherical symmetry is a prerequisite for gravitational collapse, was not clear. Even A. Einstein did not believe in the existence of black holes. At first, R. Penrose wanted to analyze the situation without the assumption of spherical symmetry, assuming that collapsing matter has a positive energy density. To do this, he had to invent new mathematical methods and use topology. R. Penrose formulated the key *concept of closed trapped surface*, which is a closed two-dimensional surface with light rays orthogonal to the surface converging when directed into perspective. This is contrary to the spherical surface in flat space, where outwardly directed light rays diverge.

In the symmetric case, any spherical surface with a radius less than the Schwarzschild radius is a trapped surface, which makes it possible to understand the structure of a black hole, in which the radial direction becomes similar to time. Time and space are reversed, and the direction inward, towards the origin of spherical coordinates, becomes time. Therefore, it is just as difficult to get out of a black hole as it is to go back in time. The flow of time will inevitably lead any observer to the beginning of the radial coordinate, where time ends. All of the matter that formed the black hole resides in that one moment in time, the singularity. Further, R. Penrose proceeded to prove that, as soon as the captured surface was formed, it is impossible within the framework of the general theory of relativity and with a positive energy density to prevent the collapse towards the singularity (Fig. 2).

For space-time visualization, R. Penrose used the method of conformal transformations, which can change the scale, but keep the angles. This allows points infinitely far in space and events in the infinite past or future to be transferred from infinity to fit into

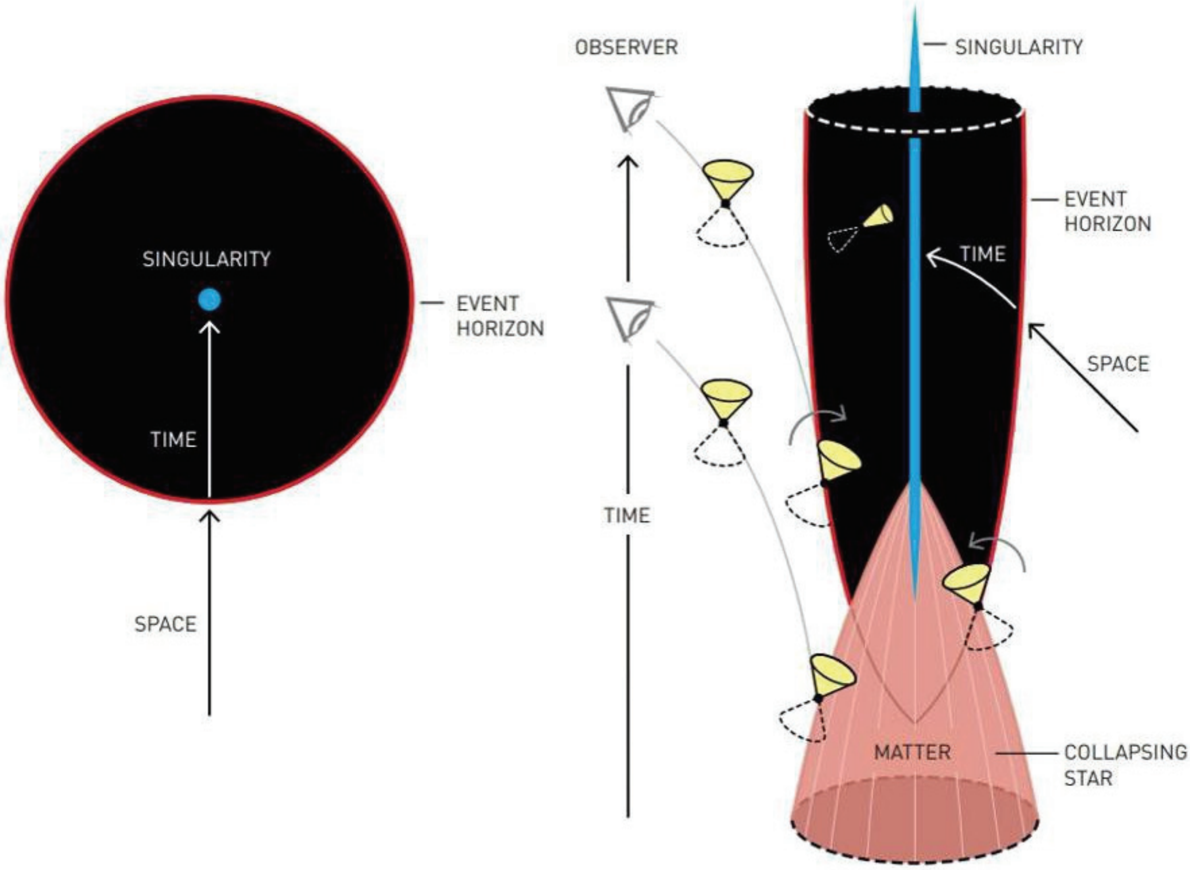

Fig. 2. Penrose diagram (1965) shows the collapse of matter into a black hole: on the trapped surface, all the light cones topple inward, and the formation of a singularity is inevitable [3] (© Johan Jarnestad / The Royal Swedish of Sciences)

finite size charts. If the light beam initially fits the line at 450, it will remain at the same angle after the conformal transformation. Such diagrams are called Penrose diagrams; they are indispensable in the study of curved space-time. This achievement of Penrose is declared to be the first result after A. Einstein in the general theory of relativity. It proves that gravitational collapse cannot be stopped once the trapped surface has formed.

The discovery of R. Penrose marked the beginning of a new era in physics and astronomy. Dark objects are deeply embedded in the modern picture of gravity. After his discoveries, the "black hole" finally became the name of this exotic gravitational anomaly [3].

In 1969, R. Penrose realized that the rotational energy of a black hole could be an important source of energy. He discovered that it was possible to use the ergosphere to extract energy: if magnetic fields were present, they would be carried along with the ergosphere, so a spinning black hole could act as a giant electrical dynamo at the center of galaxies.

Thus, the discovery of the singularity theorem by R. Penrose showed that the concepts of black holes are a reliable consequence of the general theory of relativity, forming naturally in areas heavily overloaded with matter. Subsequent technological advances have confirmed much. LIGO observations, awarded the Nobel Prize in Physics in 2017, and the unique observations of R. Genzel and A. Ghez, as well as a wonderful photograph of the center of the Galaxy M87, confirm the existence of supermassive black holes.

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Conflict of interests

The authors declare no conflicts of interest.

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