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Roger Penrose and Black Holes

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Abstract: *The article discusses, proposed by Roger Penrose, the revolutionary method of "collapse" of collapsing bodies of various shapes, and the role of a singularity - some special surface inside a black hole with an infinite curvature of space-time, near which almost any physical body collapses. The article indicates that in light of the latest discoveries of galactic dark matter and intergalactic dark energy, which form 95% of the mass energy of the Universe, Roger Penrose's conclusions do not look so straightforward. After the discovery of dark matter, the further development of the theory of the origin and evolution of black holes lies on the path of abandoning Einstein's geometric theory of gravity in general relativity and recognizing the fifth fundamental interaction between dark and baryonic matter as a structure-forming factor inside black holes.*

Keywords: *dark matter; halo; collapse; black hole*

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1. Introduction

In the formulation of the Nobel Committee it is written that the prize is awarded to Penrose for "the discovery that the formation of black holes is a reliable prediction of general relativity." This formulation reflects the fact that even before Penrose's work it was known that a sufficiently dense object (for example, a gas cloud, a star, or a cluster of stars) can collapse into a black hole. However, previous calculations were based on many assumptions, the most important of which were the spherical shape of the objects in question and various simplifying assumptions about the properties of collapsing matter. Penrose was able to propose a new revolutionary method that allows you to establish the possibility of collapse without any special assumptions about the nature and geometry of the "collapsing" body under a few simple conditions. The foundations of this method were formulated in Penrose's classic 1965 work, "Gravitational Collapse and Space-Time Singularities" published in Phys. Rev. Lett. 14, 57. [1]. In the article, he showed that if the conditions that are expected inside the black hole are met (namely: the radiation front emitted outside by some closed surface begins to compress), as well as some other, quite expected requirements, inside the black hole some light rays cannot be continued and must break off after completing the final path. In such cases, they say that the light ray rests on a singularity - some special surface that serves as the boundary of space-time. At present, we are sure that physically singularities coincide with surfaces that have a formally infinite curvature of space-time, near which almost any physical body collapses, although Penrose's theorem does not in any way determine their physical meaning, but simply guarantees their presence inside black holes. This work has long been included in textbooks on general relativity (GR), it served as the beginning of its completely new and non-trivial development, in which Penrose, Stephen Hawking and other famous scientists took part. The resulting new area of research is sometimes called "global Lorentzian geometry." Let us discuss some important assumptions and the main idea of the proof of Penrose's theorem. First, it was assumed that space-time is "predictable" in the following sense: somewhere in the past, at some point in time, one can set some initial parameters that completely determine the subsequent evolution of both matter and space-time itself. In January 1965, just 10 years after Einstein's death, Penrose discovered that black holes can and do form, detailing them in an article that is even today a major contribution to science. Penrose found that black holes are based on an infinitely dense core called a singularity, where laws unknown to us operate. Roger Penrose has shown, using elegant mathematical models, that the very existence of black holes is a direct consequence of Albert Einstein's theory of relativity. In fact, Einstein did not believe that such heavyweights - objects that devour everything, even light falling within their limits - even existed. Even so, his general theory of relativity predicts that gravity is the result of the curvature of spacetime. According to this theory, massive objects (such as black holes) leave cosmic indentations in this space-time fabric, so that other nearby objects cannot help but fall into these gravity holes. One of the predictions of general relativity is that black holes have an event horizon, a boundary beyond which nothing, not even light, can escape. In light of the latest discoveries of galactic dark matter and intergalactic dark energy, which make up 95% of the mass energy of the Universe [2], Roger Penrose's conclusions are not so straightforward:

First, the rotating massive core of a black hole, as was experimentally proved on January 30, 2020 by astrophysicist Vivek Venkatraman Krishnan, can the rotating a halo of dark matter surrounding not only a rotating white dwarf, but also another object in the Universe [3]. At the same time, a gravitational funnel is formed, similar to Einstein's gravitational funnel, which he forms, in the absence of dark matter, not yet discovered in his time, by the fabric of space-time. My suggestion looks much more plausible than the rotation of space-time. After all, the halo of dark matter is a real object, and the fabric of space-time is the ephemeral material in which the king was dressed in Andersen's fairy tale “The Naked King”. It follows that the geometric nature of Albert Einstein's gravity must be replaced by the field one. Today, researchers of the nature of gravitational forces can be conditionally divided into two groups - those who continue to search in line with the geometric approach that underlies the general theory of relativity and those who refuse to link the gravitational field with the geometry of space-time and develop the field concept of gravity. The field concept of gravity allows one to describe the gravitational interactions of bodies similar to the electric and magnetic interactions and does not contradict other experimentally substantiated approaches to describing the phenomenon of gravity and inertia, in particular, some models involving a quantum vacuum (dark matter), like a superfluid space environment. By the way, for the discovery of the rotating nucleus of a superblack hole in the center of our galaxy, two other physicists, German Reinhard Henzel and American Andrea Gez, became laureates of the 2020 Nobel Prize, along with Roger Penrose.

Secondly, the presence of a singularity inside a black hole - some special surface that serves as the boundary of space-time, Penrose's theorem does not determine their physical meaning, but simply guarantees their presence inside black holes. The general theory of gravity, followed by the theory of Roger Penrose, is not able to describe the behavior of the system and, in particular, the black hole in dynamics, since the formation of new particles and objects in the process of the development of the black hole leads to a violation of symmetry in time. J. Wheeler was right when he wrote about this: “The object that is central to the entire classical general theory of relativity, the “four-dimensional geometry of space-time” simply does not exist if we go beyond the classical approximation. This argument shows that the concepts of space-time and time are not fundamental to the structure of Einstein's physical theory. There is neither space-time nor time; there is nothing before and after. The question is what will happen the next moment, it is pointless to ask in general relativity.” [4]. In order for Einstein's general relativity to have symmetry breaking in time, since the production of particles corresponds to an irreversible process, Nobel Prize laureate Ilya Prigogine proposed to supplement the number of variables included in the standard model. The pressure P, the mass-energy density σ and the radius of the Universe R (t), he proposed to add a variable n - the density of particles and an additional equation that would connect the Hubble function with the radius of the Universe R (t) and the creation of particles n. In this case, a term appears which we, comparing with Newtonian physics, identify with pressure. To the usual pressure P we add additional pressure Padd., Due to the production of particles [5]. Thus, space-time in a black hole in Penrose's theory is “predictable”, that is, at some point in time, you can set some initial parameters that completely determine the subsequent evolution of both the black hole and the space-time itself. This state of the system corresponds to the concept of a time horizon during which we can predict the behavior of the system, its trajectory of development, and beyond the time horizon the initial state of the system can no longer serve as a basis for prediction. The transition of the system to a qualitatively new level, in the process of which the system becomes non-integrable, irreversible processes prevail in it, and time loses the property of invariance and its behavior is probabilistic, the vector character requires abandoning the invariant equations of general relativity and the theory of Roger Penrose [6].

Third, 55 years after the appearance of Roger Penrose's article “Gravitational Collapse and Space-Time Singularities” in the pages of the same journal Phys. RevLett.125.181301 was published an article by Professor Frank Sauersig and three colleagues “Finite Amplitudes of Quantum Gravity: No

Bindings" with the rejection of string theory and general relativity, which underlies M-string theory and other versions of this theory [7]. The authors propose to use gravitationally-mediated scattering of scalar fields in describing black holes, based on the parametrization of the Lorentzian quantum effective action. In doing so, the authors state: "Our design avoids the introduction of nonlocalities or massive particles with higher spin, characteristic of string theory." [7].

2. THE HALO OF DARK MATTER

The heterogeneous medium of the quantum vacuum, dark matter, is an inhomogeneous polarization medium that, due to its gravitational properties, forms vacuum domains and a dark halo of galaxies. Dark matter in astronomy and cosmology, as well as in theoretical physics, is a hypothetical form of matter that does not emit electromagnetic radiation and does not interact with it directly [8]. This property complicates and, perhaps, even makes it impossible to directly observe dark matter. The conclusion about the existence of dark matter is made on the basis of numerous; correspond to each other, but indirect signs of the behavior of astrophysical objects and the gravitational effects that they create. Elucidating the nature of dark matter will help solve the problem of hidden mass, which, in particular, consists of the abnormally high speed of rotation of the outer regions of galaxies. According to the results of astronomical observations of the Planck space telescope:

- Dark energy (68.3%);

- Dark matter (26.8%);

- "Ordinary" (baryonic) matter (4.9%) [2].

Dark matter forms a halo around galaxies and fills a fifth of galactic space. Out of approximately 5% of baryonic matter, 4/5 of the mass falls on the interstellar medium and only 0.5% of the average density of the Universe is concentrated in stars [2]. It has been found that a dark matter halo forms spheres around galaxies, stars, planets and black holes, which rotate with them (Fig. 1) [8].

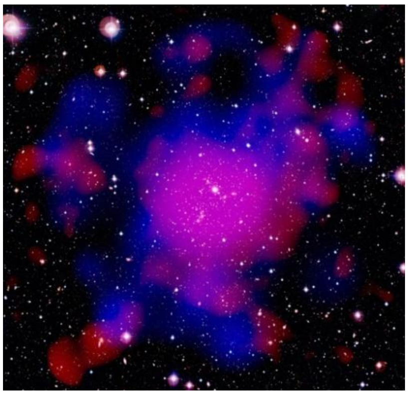

Figure1.*Components of the cluster of galaxies Abell 2744. White color - galaxies, red color - hot gas and blue color - dark matter.*

In this article, I propose a new interpretation of recent astrophysical discoveries within the framework of a new cosmological model. So the last discovery of Dr. Vivek Venkatraman Krishnan, an astrophysicist from the Max Planck Institute for Radio Astronomy in Bonn, (Germany), the rotation of space-time around a white dwarf in the PSR J1141-6545 binary star system (Fig. 2) can be interpreted as the rotation of a dark matter halo [9].

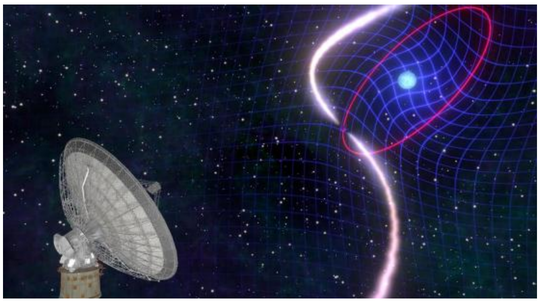

Figure2.*The illustration of Lense-Thirring frame-dragging resulting from a rotating white dwarf in the PSR J1141-6545 binary star system.*

Scientists at the Harvard and Smithsonian Center for Astrophysics in the United States have carried out detailed simulations of mysterious dark matter to reveal its alleged properties. Universe Today reports on unexpected results. The researchers hypothesized that dark matter is composed of weakly interacting massive particles (WIMP) with a mass that is about a hundred times that of a proton. In the model, such dark matter formed halos around galaxies. However, it turned out that halos can have completely different masses: from the mass of the planet to the masses of galactic clusters. They have a characteristic texture, becoming denser from the edges towards the center. At the beginning of 2020, scientists managed to register small clumps of dark matter - only 1 / 10,000 and even 1 / 100,000 of the mass of the Milky Way. And for dark matter, these are really very small values. Detection is made possible by gravitational lensing of light. If there are even small clumps of dark matter in the foreground galaxy or on the line of observation, the observed picture is distorted. Based on these distortions, it is possible to draw a conclusion about the size of the clumps. As you know, massive objects can refract light rays. Not much, but at large distances of millions of light years, the deviations will be noticeable. This characteristic gives rise to the effect of gravitational lensing, due to which we can see light from distant stars that are behind galaxies or other massive objects (Fig. 3)

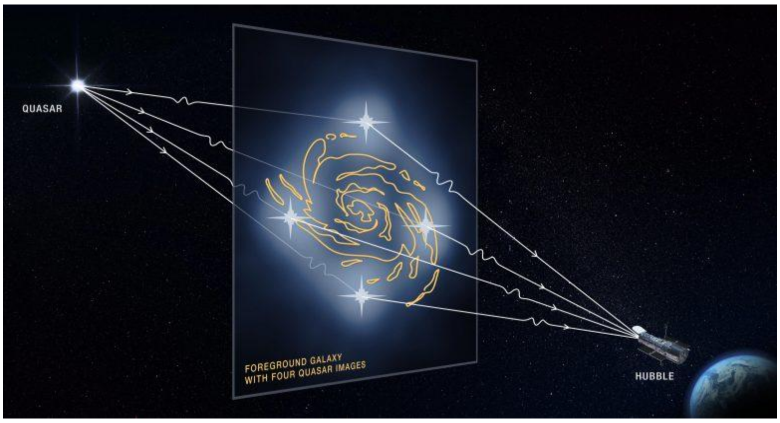

Figure3. *The effect of gravitational lensing*

Hubble's observation provides new insights into the nature of dark matter and its behavior. “We did a very convincing observational test for the cold dark matter model and it passed with flying colors,” said Tommaso Treu of the University of California Los Angeles (UCLA), a member of the observer group [10]. Scientists at the Harvard and Smithsonian Center for Astrophysics in the United States have carried out detailed simulations of mysterious dark matter to reveal its alleged properties. Universe Today reports on unexpected results. One hypothesis is that when dark matter particles collide, they emit gamma rays. Most of the gamma radiation generated by dark matter will come from a small halo. Since the scale of the halo can affect the energy spectrum of gamma rays, this model allows specific predictions about the excess of gamma rays that is observed in the center of the Milky Way. The quantum vacuum, as a cosmological medium in the new model, by analogy with the superfluid ^{3}He-B, has two phases: dark energy and dark matter. The phase state of the quantum vacuum, which characterizes dark energy, which has antigravitational properties that provide the rapidly expanding space of the intergalactic Universe, is considered in the superfluid cosmological model of quantum vacuum as an analogue of the superconducting α-phase ^{3}He-B, while it is assumed that dark matter can be considered as an analogue of β-phase ^{3}He-B, formed in strong gravitational and electromagnetic fields of galaxies and black holes, and acquired gravitational properties with increasing mass and density of dark matter [8]. The authors of the article "Fundamental dissipation due to bound fermions in the zero-temperature limit" physicist Samuli Autti et al. Found that particles in a superfluid adhere to an object, protecting it from interaction with a bulk superfluid, thus preventing the decay of a superfluid [11]. “Superfluid helium-3 feels like a vacuum to a rod moving through it, even though it's a relatively dense liquid. There is no resistance, no resistance, ”said physicist Samuli Autti of Lancaster University in the UK. "I find it very intriguing." A superfluid liquid is a liquid that has zero viscosity and zero friction and therefore flows without loss of kinetic energy. They are relatively easy to make from bosons of the isotope helium-4, which, when cooled to just above absolute zero, slow enough to overlap and form a cluster of high-density atoms that act as a single “superatom.” However, these “superatoms” form only one type of superfluid liquids. Quantum vacuum (dark matter), by definition, is in a lower energy state with respect to baryonic matter. The behavior of dark matter in this energy state is similar to the behavior of atoms in a Bose-Einstein condensate (quantum fifth state of matter) obtained at a temperature of matter close to absolute zero -273.5 Celsius or 0 Kelvin (Figure 4).

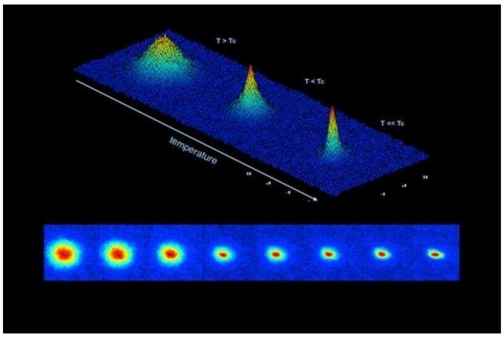

Figure4. *Bose-Einstein Condensate (BECs)*

Now physicists say that instead of studying empty space, they can create a Bose-Einstein condensate and study the quantum vacuum. In it, sound particles and photons are heard in the background vacuum. The sound is not generated by the detector, but it is heard due to the acceleration. The Unruh effect creates a thermal response of an accelerated detector as it moves in a vacuum. Researcher at the University of Nottingham Sebastian Ern believes that this effect cannot be directly observed. A special measuring device is required that can accelerate in a microsecond to the speed of light. And then under such conditions it will be possible to observe the minimum value of the Unruh effect. But in reality this cannot be done. Physicists believe that so-called quantum stimulants can be used to observe the intended effect. It is possible that different quantum systems are explained in this way [12]. Modeling one system with another will make it easier to understand black holes Analog models of black holes can be created in the laboratory.

Another type of superfluid liquid is based on the boson sibling, fermion. Fermions are particles that include atomic building blocks such as electrons and quarks. When cooled below a certain temperature, fermions bond into so-called Cooper pairs, each of which consists of two fermions, which together form a composite boson. These Cooper pairs behave exactly like bosons and can therefore form a superfluid liquid.The team created their fermionic superfluid liquid from helium-3, a rare isotope of helium that is missing one neutron. When cooled to one ten-thousandth of a degree above absolute zero (0.0001 Kelvin, or -273.15 degrees Celsius), helium-3 forms Cooper vapor (Fig. 5) [11].

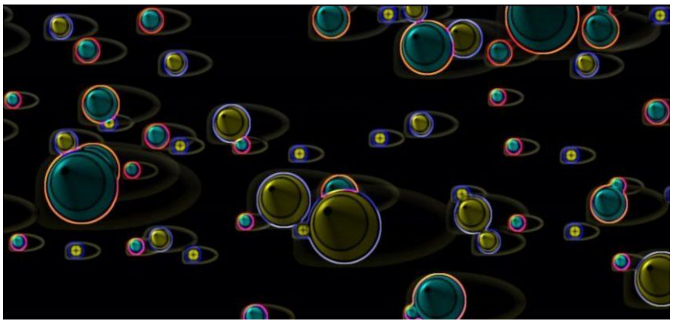

Figure5. *Medium of superfluid liquid helium-3*

The macroscopic approach, in which the hydrodynamic attachment of mass to spherical bodies of any nature (including charged clusters) into superfluid ^{3}He-B (analogue of dark matter), was outlined by Stokes back in the century before last allows us to speak of a violation of the equivalence principle, which formed the basis of the geometric theory of gravity Einstein's general relativity. We are talking about a complex force F (ω), acting from the side of the liquid on a sphere of radius R, performing periodic oscillations with frequency ω. Within small Reynolds numbers, we have [13]:

$$\mathbf{F}(\omega)= 6\pi\eta R\left(1+\frac{R}{\delta(\omega)}\right)V(\omega)+3\pi R^2\sqrt{\frac{2\eta\rho}{\omega}}\left(1+\frac{2}{9}\frac{R}{\delta(\omega)}\right)i\omega V(\omega), \quad (1)$$

$\delta(\omega) = (2\eta/\rho\omega)^{1/2}$

where ρ - fluid density, η – viscosity, V – velocity amplitude sphere, δ (ω) - the so-called viscous penetration depth, which increases with an increase in viscosity and a decrease of the oscillation frequency.

The real part of the expression (1) is a known Stokes force derived from the movement of fluid in the sphere. Imaginary component (coefficient of iωV) is naturally identified with the effective mass of the cluster added:

$$Meff\ (\omega R) = \frac{2\pi\rho R^3}{3}\ [1 + \frac{9}{2}\frac{\delta(\omega)}{R}] \qquad (2)$$

Origin added (attached) mass Meff (ωR), depending on the frequency ω and the radius R of the sphere of the cluster associated with the excitation of the field around a moving cluster of hydrodynamic velocity υ_i (r) and the appearance in connection with this additional kinetic energy. In superfluid, additional mass has two components: superfluid and normal [13]. Nobel Prize laureate Professor I. Prigogine called this effect "an active influence on the system from the outside with the transition of the system to a nonequilibrium state" [5]. The participation of the quantum vacuum (dark matter) in all interactions causes a rejection of the paradigm of the evolution of a closed system and requires a revision of all conservation and symmetry laws. For decades, we have known about four fundamental forces: gravity, electromagnetism, and strong and weak nuclear interactions. The experimental discovery of the fifth force is associated with the participation of the quantum vacuum (dark matter) in all interactions inherent in baryonic matter [8]. The new scalar field may belong to a hypothetical dark matter particle, a protophobic X-boson, which, like the Higgs boson, creates a scalar field responsible for the fifth interaction between dark matter and ordinary (baryonic) matter [14]. It is dark matter that revolves around the core of a black hole of baryonic matter, forming a gravitational vortex and providing, through the fifth interaction, Roger Penrose structures and other structures, as yet unknown to us, inside the black hole. In 2019, the Event Horizon telescope snapped M87, the world's first photograph of a black hole. This hole is located in the center of the galaxy of the same name, also known as NGC 4486, it is about 6.5 billion times more massive than the Sun and throws streams of incandescent "semi-digested" stellar matter into space (Fig. 6).

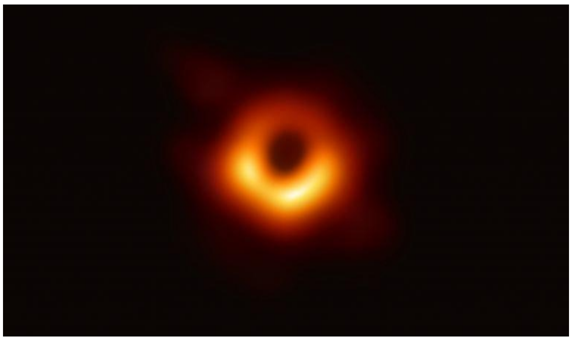

Figure6. *Famous photo of a black hole in the galaxy M87*

The substance erupts from a black hole at a speed significantly higher than the speed of light. Although the erupted substance takes the form of an elongated ray, it does not look like a uniform stream - it is rather lumpy, inhomogeneous clumps of hot material flying on the crest of a longitudinal gravitational wave (Figure 7). The results of the latest study are presented in a paper published in the Astrophysical Journal [15].

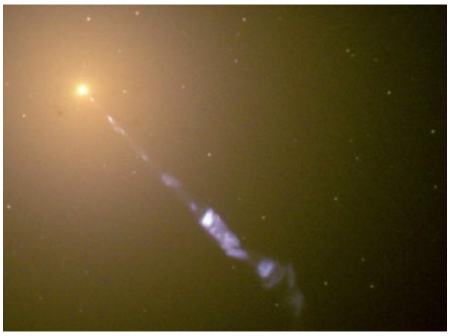

Figure7. *The flow of matter discharged from a black hole NGC 4486 at a speed 6.3 times the speed of light*

In the laboratory, for the first time, a substance was obtained that has properties identical to the plasma in the vicinity of a black hole. This is stated in the joint work of Russian, Japanese and French scientists [16]. In laboratory conditions, accretion disks of a black hole were obtained. This is the kind of structure that results from diffuse material with rotational moment on a massive central body. Such disks also appear around stars in close binaries, in rotating galaxies and in protoplanetary formations. In addition, a similar substance appears in the mechanism of gamma-ray bursts accompanying the merger of neutron stars and the collapse of the cores of supernovae and hypernova stars. The compression of matter, as well as the release of heat as a result of the friction of the differentially rotating layers, leads to the heating of the accretion disk (Figure 8).

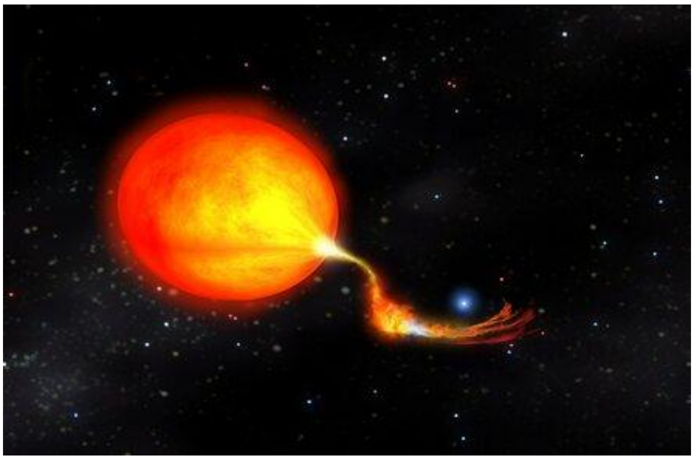

Figure8. *Formation of an accretion disk around a pulsar*

Gas flowing from one component of the system to another has a significant angular momentum: it appears due to orbital motion. Therefore, gas particles cannot fall on the star radially. Instead, they move around it in Keplerian orbits. As a result, a gas disk is formed, in which the distribution of velocities corresponds to Kepler's laws. According to it, the layers located closer to the star will have high speeds. However, due to friction between the gas layers, their velocities equalize, and the inner layers transfer part of their angular momentum outward. As a result, the inner layers approach the star and eventually fall to its surface. In fact, the trajectories of individual gas particles are in the form of spirals that slowly twist. The radial displacement of matter in the accretion disk is accompanied by the release of gravitational energy, part of which is converted into kinetic energy (acceleration of gas movement when approaching the star), and the other part is converted into heat and heats the disk matter. Therefore, the accretion disk emits thermal electromagnetic radiation. The kinetic energy of the gas upon collision with the surface of the star is also transformed into thermal energy and radiated. The main property of the formation of such X-ray sources will be strong magnetic radiation. Its magnetic field and induction can reach several thousand Tesla, researchers from the LaPlaz Institute, NRNU MEPhI and the CELIA laboratory of the University of Bordeaux note in their work [16]. The uniqueness of the experiment is that the parameters of the obtained plasma do not need to be scaled; they correspond to the actual parameters of the plasma in the vicinity of the black hole of close binary systems of the Cygnus X-1 type. Philip Korneev, associate professor of the Institute of Laser and Plasma Technologies of NRNU MEPhI and a participant in the experiment says: “The essence of the method is the effect of reflection of a powerful laser beam along the spiral inner surface of the target. The target becomes a folded piece of foil, the size of which is several hundred microns. The laser beam supplies energy 330 Joules with a duration of one picosecond Thus, it was almost completely absorbed in the target cavity, creating a relativistic plasma inside and a magnetic field with an induction of more than 2 thousand Tesla. seconds, the pulse power turned out to be about 20 times higher than the consumed power of the entire energy of the Earth !!! After that, matter with a temperature of billions of degrees, a density of 10^{18} particles per cm^3 and a frozen-in magnetic field of more than 2000 Tesla was formed in the target volume for several picoseconds. parameters can be found in plasma in the active region and x-ray sources. The volume of incandescent magnetized matter was sufficient to have the main characteristics of its cosmic prototype. This was also facilitated by the experimental conditions, in particular, the fact that inside the plasma volume the magnetic fields were directed towards each other in such a way that in the area of contact of the opposing magnetic lines, the annihilation occurs of the magnetic field”. The polarization of the quantum vacuum (dark matter) in this place leads to leading to the emergence of particle fluxes with speeds close to the speed of light. (Fig. 9).

Figure9. *Simulation of a black hole*

The experiment showed that the technique developed by an international group can create not only quasi-stationary magnetic fields of record magnitude, but also simulate the state of the plasma arising in them with a high energy density of matter and electromagnetic energy in the vicinity of a black hole.

3. Conclusion

Thus, highly appreciating the contribution of the Nobel Prize Laureate Roger Penrose to the theory of black holes and his revolutionary method, which made it possible to establish the possibility of collapse without any special assumptions about the nature and geometry of the "collapsing" body, we have to state that after the discovery of dark matter, further development theory of the origin and evolution of black holes, lies on the path of rejection of the geometric theory of gravity of general relativity of Einstein and the recognition of the fifth interaction between dark and baryonic matter.

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