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Hawking Radiation and Maxwell's Demon

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Abstract

The mechanism of the birth of matter in the Universe was proposed by Professor Stephen William Hawking as the effect of radiation of particles by a black hole and experimentally implemented by specialists from the Israel Institute of Technology in 2021. They also proposed in the future to extract energy from black holes using a singular reactor. Maxwell's Demon, the simplest and, apparently, the first thermodynamic model in the literature, takes part in this process.

Keywords: Black Hole, Hawking Radiation, Elementary Particles, Maxwell's Demon.

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Introduction

In recent years, deep analogies with thermodynamics have been discovered in the physics of black holes. If we assume that the surface area of a black hole is proportional to entropy, and surface gravity is proportional to temperature (in thought experiments of the interaction of a black hole with a body falling on it, these assumptions are confirmed), then we can formulate the laws of black hole physics that are equivalent to the corresponding laws of thermodynamics. In September 2021, Professors Xavier Calmette and Folkert Kuiper's from the Department of Physics and Astronomy at the University of Sussex published a report that the structure of black holes is more complex than previously thought, and quantum gravity could lead to black holes pushing against the quantum medium. Xavier Calmette wrote: "Our discovery that Schwarzschild black holes have a pressure as well as a temperature is even more interesting considering that it was a complete surprise. Hawking's important intuition that black holes are not black, but have a radiation spectrum very similar to that of a black body, makes black holes an ideal laboratory for studying the interplay between quantum mechanics, gravity, and thermodynamics" [1]. However, today a blatant contradiction arises in Planck's theory and this is connected with the thermodynamics of black holes. How does the huge energy nhν, where n can be a very large number, go to one oscillator with a negligible average energy U? In addition, we add that the frequency ν in the radiation spectrum changes continuously from zero to infinity without any distinguished harmonics, and it becomes completely incomprehensible and illogical that a single oscillator should have a huge number of such frequencies in its stock. It turns out that in the visible region of the spectrum, the oscillator can be excited to a huge energy nhν, comparable to the energy of hard X-rays, but at the same time it can emit only a small piece of this energy hν, and the rest of the energy of the oscillator (n-1)hν is, as it were, "frozen " and cannot be realized in any form, at least in nonradiative processes. A similar paradox in Planck's quantum theory was also found in nanotechnology. On July 21, 2020, a scientific group from Peter the Great St. Petersburg Polytechnic University was able not only to detect, but also theoretically explain a previously unknown physical phenomenon - an increase in the amplitude of mechanical vibrations without any external influence [2]. Members of the scientific group V.A. Kuzkin and A.M. Krivtsov discovered a physical paradox, according to which the excitation of mechanical vibrations occurred due to internal thermal resources. This open physical phenomenon is called ballistic resonance (Figure 1) [2].

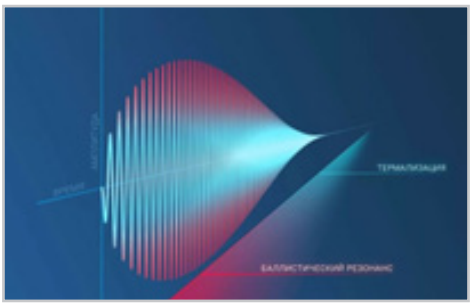

Figure 1: A new physical phenomenon - ballistic resonance

The phenomenon of ballistic resonance lies in the fact that during the course of the heat equalization process, mechanical vibrations arise in the crystal lattice of the material, the amplitude of which increases with time. At the same time, it turned out that heat at the nano- and microlevels can flow from cold to hot, which leads to the appearance of completely new physical effects. But the growth does not occur indefinitely, but reaches a certain value and then gradually comes to naught, and the tem-

perature equalizes along the entire crystal. However, one of the formulations of the 2nd law of thermodynamics says that heat cannot spontaneously flow from a cold body to a hot one. We are now considering non-equilibrium thermodynamic states that develop precisely according to the Clausius scenario. In this scenario, spontaneous processes flow towards equilibrium, in which all system parameters dissipate their gradients. There is one exception to evolution according to Clausius, which is formulated in the form of Maxwell's demon. That is, if you create physical conditions under which the Maxwell demon will work, then it will be possible, including the flow of heat from a body with a lower temperature to a body with a higher temperature. Maxwell's demon is a thought experiment proposed by Maxwell in 1871. First of all, we are talking about a closed system. The proposed apparatus consists of a simple rectangular parallelepiped containing an arbitrary amount of gas. The cuboid is divided into two sections of the same size with the same, uniform temperature. A demon sits on the separating wall section, carefully selecting randomly scattered particles so that all particles with high kinetic energy are collected in one section, and the rest - with low kinetic energy - remain in another (Figure 2).

Figure 2: Maxwell Demon Gate

We can say that this demon is a metaphor for a device or machine capable of carefully analyzing the speed or kinetic energy of each particle in the container. Thanks to this process - the action of Maxwell's demon - all high-energy particles are subsequently driven into one section. The demon raised the temperature of one part of the box compared to the other. We can say that this demon is a metaphor for a device or machine capable of carefully analyzing the speed or kinetic energy of each particle in any container. In the works of V.A. Kuzkin and A.M. Krivtsov implemented just such a variant of physical conditions for the Maxwell demon. And in these physical conditions, everything is determined by resonances and phase shifts [2]. The authors themselves write about this: “In order to understand the essence of the process, one can imagine the most ordinary swing. So, it was generally accepted that without external influence it is simply impossible to achieve oscillatory resonance. ... But the scientific group discovered a physical paradox, according to which the excitation of mechanical vibrations occurred due to internal thermal resources (that is, the swing swung by itself). The phenomenon of ballistic resonance lies in the fact that during the course of the heat equalization process, mechanical vibrations arise in the crystal lattice of the material, the amplitude of which is raster over time” [2]. That is, if different subsystems of one system that move in resonance but with a phase shift are considered as swings and external influences, then it is possible to transfer energy from a subsystem oscillating with a lower amplitude (temperature) to a subsystem oscillating with a larger amplitude (temperature). In this case, the resonant frequencies do not have to coincide, but their multiplicity is sufficient. If, at the same time, one learns to divert part of the energy from the subsystem that increases the amplitude of its oscillations, then this will be a perpetual motion machine of the second kind. Consideration of the Maxwell demon in the Leo Sapogin’s Unitary Quantum Theory as a system of two potential barriers leads to the conclusion that the 1st and 2nd laws of thermodynamics are violated. This conclusion is confirmed by experimental data [3].

Hawking Radiation

At the edge of a black hole, the physical vacuum is in a conditionally stressed state, as a result of which it polarizes in a quantum way. Nothing of the kind follows from Einstein's general theory of relativity. Einstein's general theory of relativity is, generally speaking, incompatible with quantum concepts [4]. Studying the behavior of quantum fields near a black hole, Stephen Hawking predicted that a black hole necessarily radiates particles into outer space and thereby loses mass [5]. This effect is called Hawking radiation (evaporation). Simply put, vacuum polarization occurs under the influence of monstrous gravitational and magnetic fields, as a result of which the formation of not only virtual, but also real particle-antiparticle pairs is possible. According to Hawking, on the surface of the event horizon, the direction of scattering of the generated particles ceases to be random, i.e. becomes polarized, namely orthogonal to the black hole surface [5]. This is where the Maxwell Demon's particle selection mechanism comes into play. Particles with higher energy form stable Hawking radiation - the process of emission of various particles by a black hole. The reality of such radiation was first proved by specialists from the Israel Institute of Technology. The experiment, conducted by Israeli scientists, had to be repeated 97,000 times over 124 days. To create an analogue of a black hole with a length of 0.1 millimeters, the researchers needed 800 rubidium atoms. It is assumed that in the future, specialists will be able to extract energy from black holes using a singular reactor. According to the theory, the energy will be generated by Hawking radiation with the participation of Maxwell's Demon. The scientific material describing the creation of a black hole model in the laboratory was published on February 19, 2021 on Phys.org. [6]. As a result, a huge amount of matter is ejected into the surrounding space of the black hole. This substance is a plasma of the most elementary particles of the Universe. In fact, this is a huge and at the same time very dense plasma cloud that retains the shape of a disk. The speed of its rotation is close to the speed of light, and the direction of rotation coincides with the direction of rotation of the original black hole. Modern astronomers call such a disk a quasar (Figure 3).

Figure 3: Light emitted by quasar J1120+0641, 13 billion light-years from Earth.

By the way, for the discovery of the rotating core of a superblack hole in the center of our galaxy, the 2020 Nobel Prize winners, along with Roger Penrose, were two other physicists, the German Reinhard Genzel and the American Andrea Ghez. In the new cosmology, the halo of dark matter can act in the primary Universe as that sufficiently dense object that can shrink (collapse) under the action of gravitational forces into a black hole. The question arises whether such astrophysical configurations of the nucleus–halo of dark matter can form at all and whether they remain stable on cosmological time scales. The authors of the new article Carlos R Argüelles, Manuel I Díaz, Andreas Krut, Rafael Yunis "On the formation and stability of fermionic dark matter haloes in a cosmological framework" give an affirmative answer to this question [7]. Moreover, the results obtained prove that a dark matter halo with a core–halo morphology is a very probable outcome in the nonlinear stages of black hole structure formation. In laboratory conditions, in 2020, for the first time, accretion disks of a black hole were obtained, which have properties identical to plasma in the vicinity of a black hole [8]. This is a structure that results from diffuse material with torque onto a massive central body. The compression of matter, as well as the release of heat as a result of friction of differentially rotating layers, leads to heating of the accretion disk. Plasma flowing from one component of the system to another has a significant moment of rotation: it appears due to orbital motion. Therefore, plasma particles cannot fall radially on the star. Instead, they move around it in Keplerian orbits. As a result, a plasma disk is formed, in which the distribution of velocities corresponds to Kepler's laws. According to him, the layers located closer to the star will have higher velocities. However, due to friction between the layers, their velocities equalize, and the inner layers transfer part of their angular momentum to the outside. As a result, the inner layers approach the star and eventually fall onto its surface. In fact, the trajectories of individual plasma particles have 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 up the substance of the disk. 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, National Research Nuclear University MEPhI and the CELIA laboratory of the University of Bordeaux note in their work [8].

Researchers at the University of Manchester, led by Nobel Prize winner Andre Geim, discovered in 2022 that inside graphene it is possible to recreate conditions identical to those in which matter arises from vacuum in the vicinity of black holes and other space objects [9]. In experiments with very narrow strips of graphene, they reproduced the Schwinger effect, in which super-powerful electric or magnetic fields act on a vacuum in such a way that some of the pairs of virtual particles and antiparticles that form dipole structures are positronium. The dipole structures of positronium will decay and form quite real positrons and electrons, as well as other types of matter and antimatter forms [9]. Positronium has stable compact states with high binding energy, which can be interpreted as particles and elementary cells of the quantum vacuum structure. The mass of positronium is equal to two electrons, and the dimensions are twice the diameter of a hydrogen atom. The ground state of the positronium structure cell has the energy E = 3727.7763161411854 eV. In the work of RAS Academician R.F.Avramenko, it was shown that the excited states of the vacuum have a lower energy than the ground state. And this is a direct opportunity to access an inexhaustible and clean source of energy [10]. The structure of positronium was first discovered experimentally in 1951 by the German physicist Martin Deutsch (Figure 4) and reliably established by Professor D.B. Cassidy and his assistant A.P. Mills Jr. in 2007 [11].

Figure 4: Structure of positronium

Cassidy and Mills calculated that in their experiment the density of positronium atoms was 10^{15} per cm^3. Calculations show that with an increase in this density by three orders of magnitude, these atoms at a temperature of 15 kelvin will merge into a single quantum system - the Bose-Einstein condensate [11]. The substance of a plasma disk formed by Hawking radiation in the vicinity of a black hole is gradually stratified into electrons-positrons and neutrons. The mass appearance of neutrons on the outskirts of the plasma disk marks a fundamentally new stage in the life of the formation of the universe. From this moment, the assembly line for the production of chemical elements begins to work. Experimental physics has established for certain that a free neutron decays into a proton and an electron after about 15 minutes. Thanks to this, the most common substance in the universe, hydrogen, is born at the output. Professor Vladimir Strelnitsky's article “Masers, Lasers and the Interstellar Medium” discusses the results obtained in three areas of astrophysics: interstellar supersonic turbulence, circumstellar disks, and natural masers and lasers [12]. The masers in the hydrogen recombination lines detected by the Kuiper observatory originate in quasars surrounding massive black holes. They make it possible to study the kinematics and structure of the quasar disk. The lines of hydrogen recombination in the far infrared range turned out to be enhanced. They are the first known natural amplifiers of electromagnetic waves in the laser wavelength region. Analysis of their emission, along with emission in other recombination lines, provides a possible clue to understanding the absence of optical lasers in the Universe.

The role of Maxwell's demon, which separates excited positronium particles from unexcited ones in the vicinity of black holes, is played by inhomogeneous gravitational and magnetic fields, which deflect unexcited particles towards a strong field, and excited particles towards a weak field. This process is similar to the process implemented in the molecular generator on ammonia (Basov′s Maser)- “Maxwell's Demon of the XX century”, considered in detail by Professor R. Poplavsky in [13]. The specialists of the Israel Institute of Technology are right, who suggested extracting energy from black holes using a singular reactor based on Hawking radiation, similar to how it is implemented today in installations using coherent radiation from masers and lasers.

Conclusion

The astrophysical observations and experiments presented in the article force physicists to critically approach the standard cosmological model ΛCDM (Λ- Cold Dark Matter). The Universe is a dynamic system that continuously generates baryon masses of matter and dark matter and regulates their density, expanding its boundaries. This circumstance leads to new, more general conservation laws inherent in the physics of open systems. In the article by Professor Valery Etkin "The Perpetuum Mobile of the Universe", the concept of the dynamic Universe is substantiated, according to which the field (continuum) and corpuscular phases of matter with their inherent forms of energy are circulated in it. In this circuit, gravity plays the role of a "perpetual motion machine" that allows the Universe to function in time and space indefinitely, bypassing the state of equilibrium [14].

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