Black holes and the evolution of matter inside them.

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Abstract: It is shown that black holes, initially containing quark-gluon plasma, with a further increase in their mass, due to gravitational pressure, transform matter into photons, and then into a Bose-Einstein condensate. Photons of the Bose Condensate in the lowest energy state, having no momentum, begin to leave the black hole, which causes the black hole to explode and emit high-energy photons in the form of gamma rays that fill the Universe. That is, the evolution of matter inside black holes turns matter into light.

Keywords: Black holes, quark-gluon plasma, photons, Bose-Einstein condensate, Bose statistics, gamma-ray bursts.

INTRODUCTION.

A black hole is a region of space-time that, due to gravitational attraction, no object, even photons of light, can leave. But, nevertheless, the matter inside black holes evolves according to the usual laws of physics and eventually turns into light. More precisely, in gamma radiation. Moreover, everything happens intuitively, without any fantastic assumptions like infinitely high pressures, temperatures, and similar characteristics. Normal physical processes take place inside a black hole. Let's demonstrate this.

To begin with, let's define matter as a set of elementary particles, interactions between which lead to a visible variety of various interactions and constituent particles. Therefore, in order to understand what is happening inside a black hole, it is enough to analyze the behavior of elementary particles inside a black hole, that is, at a sufficiently large pressure. We emphasize that not at an infinitely large pressure!

It has already been shown earlier that matter in black holes is in the state of quark-gluon plasma, as a result of which the black hole consists of a small QGP “drop” and a large gravitational radius [1]. That is, at a pressure of 1.3 * 10^36 Pa and more, which is achieved in black holes, matter completely turns into a quark-gluon plasma at any temperature (according to the phase diagram). Therefore, the following equilibrium must be established inside black holes:

quark-gluon plasma pressure = gravitational pressure.

But, if we assume that the mass of the black hole will continue to increase, then this will automatically lead to an increase in gravitational pressure. Moreover, theoretically there is no upper limit of pressure inside black holes. Therefore, it is very important to analyze the processes that will occur with increasing pressure, and which will undoubtedly lead to a certain evolution of matter inside black holes.

RESULTS AND DISCUSSION.

Let me remind you that in ordinary stars the gravitational pressure is compensated by thermonuclear reactions, and when the “thermonuclear charge” burns out, this leads to the gravitational compression of the star and its transition (depending on mass) to a black hole, white dwarf or neutron star.

Quark-gluon plasma (QGP) is literally a “quark soup” of certain elementary particles (quarks, antiquarks, gluons, etc.). In general, we can say that the quark-gluon plasma is a “soup” of fermions and bosons. This “soup” of particles inside black holes is in thermal and chemical equilibrium. Therefore, according to Le Chatelier's principle, an increase in pressure or temperature will lead to such processes inside the quark-gluon plasma, which will be directed towards countering the changes.

For example, an increase in temperature and pressure in a black hole should lead to processes that will decrease the temperature and pressure inside the black hole.

Taking into account the molecular-kinetic theory and the fact that all fermions have a certain rest mass, it can be argued that an increase in the pressure and temperature of the quark-gluon plasma will lead to an increase in the concentration of massless bosons in the QGP. That is, in the general case, the concentration of photons and gluons inside the black hole will increase, since the remaining bosons (W- and Z-bosons) have a rest mass that is not equal to zero.

This follows strictly from elementary arguments. Pressure can be viewed as the summing result of the thermal motion of particles. If we act on a certain system of particles in equilibrium with additional pressure, this will always lead to an increase in the concentration and speed of these particles, and as a result, to equalization of external and internal pressures under new conditions.

If these particles are fermions (have a rest mass), then an increase in external pressure will always lead to an increase in particle velocities, up to relativistic velocities. And this is a big problem, since with relativistic effects, not only the speed, but also the mass of particles will increase. And this means that even an infinitely large external pressure will always be compensated by the relativistic effects of a system of particles consisting of fermions. This approach leads us to the existence of infinitely large external and internal pressures (inside black holes), which do not force the system to evolve in any way and are not theoretically limited by anything. Just infinity and nothing more. Naturally, this is impossible.

That is why, with an increase in pressure in the quark-gluon plasma that exists inside a black hole, the concentration of massless bosons will increase and the concentration of fermions will decrease. That is, as the external pressure increases inside the black hole, there will no longer be infinitely large pressures, since the QGP fermions will be processed into massless bosons. Massless bosons always move at the speed of light, and therefore, their pressure depends only on the energy density (particle concentration), and does not depend on relativistic effects.

These conclusions are confirmed by the statistics of Bose and Fermi, since a gas consisting of bosons has a pressure value less than the classical Boltzmann value, and a Fermi gas has a pressure greater than the classical one. Therefore, according to Le Chatelier's principle, as the pressure inside the black hole increases, fermions really should be “processed” into bosons.

“Let us consider a gas consisting of elementary particles, or particles which, under the given conditions, can be regarded as elementary...

All the formulas derived in this section have a completely similar form for both Fermi and Bose statistics, differing only in one sign...

In Bose statistics, the value of gas pressure deviates in the opposite direction - in the direction of decrease in comparison with the classical value; we can say that some effective attraction between particles appears here...” [2].

Next, we analyze the production of gluons and photons.

Gluons are gluon field quanta that carry the strong interaction between quarks. Unlike photons, gluons and quarks cannot exist in a free state, and therefore they exist only in protons, neutrons, and quark-gluon plasma.

Recall that the “tense” gluon field, which is formed, for example, in the collision of gluons or in the growth of the gluon field, begins to “break” and gives birth to a quark - antiquark pairs. Consequently, if the concentration of gluons in the black hole increases, then when a certain concentration is reached, the gluons will begin to “break” and again give birth to a quark - antiquark pairs. And this means that the equilibrium will not be able to shift towards a significant increase in gluons.

Therefore, with an increase in external pressure inside the black hole, the equilibrium will shift towards the production of photons. That is, the quark-gluon plasma will be gradually processed into photons. At a certain external pressure, the entire QGP “drop” will be converted into photons. Usually quarks annihilate with the emission of two photons. Given the mass of quarks, it is easy to understand that the annihilation of quark-antiquark pairs will lead to the production of high-energy gamma rays, which are characteristic of gamma-ray bursts.

The rest energy of quarks is [3]:

u-quark = 1.5 - 3 MeV,

d-quark = 3 - 7 MeV,

c-quark = 1.25 GeV,

t-quark = 174.2 GeV,

s-quark = 95 MeV,

b-quark = 4.70 GeV.

We also note that photons do not interact with each other and, therefore, the resulting photon gas in the QGP "drop" can be considered ideal and such that it obeys Bose statistics.

That is, we will get a black hole, in which there is a "drop" of a certain mass and radius, consisting of only photons. Moreover, the pressure of photons inside the drop will be very large. And this means that these photons, due to the high pressure inside the "drop", inevitably form a classic Bose-Einstein condensate, since with an increase in density or a decrease in temperature, the number of particles per one available energy level increases. Here's a quote:

"...That is, with a large number of particles, the relative population of the upper level is negligible. Thus, in thermodynamic equilibrium, most of the bosons will be in the state with the lowest energy, and only a small fraction of the particles will be in another state, no matter how much little difference in energy levels.

Consider now a gas of particles, each of which can be in one of the momentum states, which are numbered and denoted as |k⟩. If the number of particles is much less than the number of states available at a given temperature, all particles will be at different levels, that is, the gas in this limit behaves like a classical one.

As density increases or temperature decreases, the number of particles per available energy level increases, and at some point the number of particles in each state will reach the maximum possible number of particles in that state. Starting from this moment, all new particles will be forced to go into the state with the lowest energy…" [4].

From the quote it is obvious that at any temperature there will be a certain pressure at which bosons form a Bose-Einstein condensate. In addition, in 2018, a work by physicists was published in which Bose stars (clumps of Bose-Einstein condensate) are formed precisely under the influence of gravitational pressure [5].

Further, this giant Bose condensate, which is in the form of a "drop" inside a black hole, having quantum properties on a macroscopic scale, will fill the entire black hole and begin to leak out through the gravitational radius.

Since the pressure in a Bose condensate depends on temperature, but does not depend on volume. Note that this "condensate" is actually a gas (no real condensation occurs).

“…We see that at T < T0 the pressure is proportional to T^2.5, but does not depend on the volume at all. This circumstance is a natural consequence of the fact that particles in the state ε=0, having no momentum, do not make any contribution to pressure...

The phenomenon of accumulation of particles in the state with ε=0 is called Bose-Einstein condensation. We emphasize that in this case we can only talk about “condensation in momentum space”, no real condensation in a gas, of course, occurs...” [2, Page 203. § 62. Degenerate Bose gas].

Therefore, the photons occupying the lowest energy state (ε=0) in the Bose condensate have zero momentum, and therefore, these photons can overcome the gravity of the black hole, since their momentum does not change - it is already equal to zero.

When classical photons move in a gravitational field, they change their momentum depending on the difference in the gravitational potential at the place of registration and emission of a photon. In this case, the photon wavelength increases or decreases, depending on the change in momentum according to the de Broglie formula.

$$\text{ʎ} = h / p$$

In this case, the photon energy is equal to:

$$E = p * c = (h * c) / \text{ʎ} = h * \gamma$$

Inside a black hole, gravity is so strong that “expending” the entire momentum of an ordinary photon is no longer enough to overcome gravity, therefore, classical photons cannot leave the black hole.

But if photons don't have momentum, then gravity won't be able to stop them. And therefore, such photons can easily leave a black hole. Consequently, the photons of the Bose condensate in the lowest energy state, which have no momentum, will begin to “evaporate” from the black hole. In this case, the gravitational pressure of the black hole will force other photons (condensate), which are in higher energy states, to take the place of the departed photons. As a result, the black hole will begin to collapse and an explosion will occur with the emission of gamma rays, since the photons that have left the black hole are no longer in the Bose condensate state and again have a certain momentum.

CONCLUSION.

Thus, black holes initially containing quark-gluon plasma, with further evolution and an increase in gravitational pressure, turn matter into photons, which pass into the Bose-Einstein condensate, and then, during the collapse and explosion of the black hole, they are emitted in the form of gamma-ray bursts.

We especially note that photons that have no momentum and are in the lowest energy state of the Bose condensate can overcome the gravity of a black hole, since they essentially do not have a “gravitational charge”. This means that such photons can be compared with particles that do not have a Coulomb charge, and therefore do not respond to various electric fields.

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