Maximons and the maximon cluster hypothesis

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Limitations on the lifetime and mass of the gravity-bound systems of elementary black holes ("maximons") are determined and the possibility of detecting such systems is examined.

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Markov[1-3] proposed a hypothesis that stable particles with a mass $m_{pl} \sim (\hbar c/G)^{1/2} \sim 10^{-5}$ g ("maximons") can exist and examined the interaction of such particles with matter. Because of the extremely small cross section for interaction of maximons with ordinary matter ($\sigma_{pl} \sim 10^{-66}$ cm^2), the assumption that almost all of the unobservable matter, which determines the metrices of the universe, at present consists of maximons apparently cannot be rejected on the basis of direct observations.[3] The aim of this paper is to focus attention on the possibility for the existence (in terms of the maximon-stability hypothesis) of a fundamentally new class of celestial bodies. Specifically, we are referring to long-lived gravitation-bound maximon systems "maxi-

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mon clusters") and some specific properties of such systems. Such systems have to originate as a result of gravitational instability from the inhomogeneities in the early stages of development of the universe, if at the time of the Great Explosion the maximon component of matter was large.[1]

Let us assume that at some moment in time there developed a system with a mass $M = Nm_{pl}$ consisting of N maximons each of which had a finite motion in the common gravitational field of all the other masses. Let us estimate the lifetime of such a system. If R is the size of the system, then the average rate of motion of the maximons in the cluster (velocity dispersion) is $v \sim (GM/R)^{1/2}$ and the average period of the finite motion is $T \sim R/v \sim R^{3/2}(GM)^{-1/2}$. The characteristic time τ_0 between two close encounters of one maximon with another in the cluster, during which the direction of its motion changes significantly (scattering at an angle $\theta \sim 1$), is $\tau_0 \sim RN/v \sim M^{1/2}R^{3/2} G^{-1/2}m_{pl}^{-1/2}$. The time of the collision relaxation of such a system is $\tau = \tau_0\Lambda^{-1}$, where the factor $\Lambda \sim 10 \ln N$ is associated with the presence of unshielded, slowly decreasing gravitational forces with the distance. The problem under consideration is analogous to that of the evolution of the star clusters (see, for example, Refs. 4 and 5). The time τ is the characteristic time for the establishment of quasi-Maxwellian distribution due to the collision of particles. As a result of energy redistribution in the cluster, maximons, which have sufficient energy to leave the cluster, appear after the time τ, which causes the system to lose energy. The characteristic time of this dissipation (the lifetime of the maximum cluster) is (Ref. 5) $\tau_l \sim 30\tau \sim R_g^2\alpha^{3/2}(cl_{pl} \ln N)^{-1}$, where $R_g = 2GM/c^2$ is the gravitational radius of the cluster, $l_{pl} = (G\hbar/c^3)^{1/2}$, and $\alpha^{-1} = R_g/R = 2\phi/c^2 \sim v^2/c^2$. At $\alpha \gg 1$ the motion of particles in the cluster is nonrelativistic $v^2 \ll c^2$ and the characteristic time of the energy dissipation due to gravitational radiation $\tau_g \sim \alpha^5 R_g^2(L_{pl}c)^{-1}$ is much larger than τ_l.

As a result of energy dissipation, the internal structure of the maximon cluster gradually changes. The maximons, which acquire an energy close to the evaporation threshold, are able to move in orbits of increasing size. In the last collision, before the maximon leaves the cluster it receives on the average a much smaller energy than $m_{pl}v^2/2$, and therefore its energy GM^2/R remains almost constant during large part of the evolution of the cluster. The loss of mass of the cluster causes its size to decrease $R \sim M^2$. A decrease of the original mass M by a factor of α can reduce the size of the cluster to approximately its gravitational radius, which may form a black hole with a mass $M_1 = M/\alpha \sim GM^2/Rc^2$. If $M_1 < 5 \times 10^{14}$ g, then the black hole will collapse in a shorter time than the lifetime of the universe as a result of quantum processes of particle production.

Comparing the lifetime of the cluster τ_l with that of the universe, we can easily see that showers of maximon clusters, which were produced in the easly stages of evolution of the universe, could have occurred until the present time, if their parameters satisfy the condition $M\alpha^{3/4} \gg 10^{26}$ g.

Accretion of the surrounding matter by the cluster "contaminates" it. Since at $\alpha \gg 1$ $v^2/c^2 \sim \alpha^{-1} \ll 1$, the motion of particles captured by the cluster is nonrelativistic. To estimate the quantity of matter captured by the cluster as a result of its "contamination," we assume that the captured matter consisting of nucleons produces a nonrealtivistic degenerated gas. In this case if the density of the captured nucleons within the cluster is n, then the characteristic energy of the nondegenerated gas inside the cluster is $E \sim (\hbar^2 n^{5/3} V/2m) - mNc^2\alpha^{-1}$. Here N is the total number of particles, $V \sim R^3$ is the volume of the cluster, and m is the mass of the nucleon. The accretion of nucleons in the cluster ceases when the quantity E is greater than zero. Therefore, the characteristic density of the nucleon gas captured by the cluster is $\rho_m = mn \sim m\lambda_m^{-3}\alpha^{3/2} \sim 10^{15}(\text{g/cm}^3)\alpha^{-3/2}$, where $\lambda_m = \hbar/mc$ is the Compton nucleon wavelength. Since at $\alpha \gg 1$ this density is always smaller than the nuclear density, the considered approximation for the free-particle gas is valid. The total mass of the cluster-captured matter $M_m \sim \rho_m V \sim m\alpha^{3/2}(R_g/\lambda_m)^3 \sim 10^{-24}$ g $\alpha^{3/2}(M/10^{15}\text{ g})^3$ for a cluster with a small mass $M \ll 10^{35}$ g $\alpha^{-3/4}$ is negligible $M_m \ll M$.

The motion of a "contaminated" maximon cluster transports in space the highly dense nucleonic matter captured by it (for example, at $\alpha = 100$ this density is only two orders of magnitude smaller than the nuclear density). Because the cross section for interaction of the maximons is small, it seems that the motion of the nucleon component associated with the maximom cluster is easier to record than to directly observe the maximon component.

[1)]At least in terms of the cold model of the universe the assumption that a large number of stable maximons existed in the early stages apparently is not inconsistent with the observed data.

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