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A HAIL FROM SPACE: MORE DANGEROUS THAN AN ASTEROID

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Abstract: A new problem on the collision of a large space cloud of small dust particles and a planet atmosphere is considered. The cloud approaches the planet and enters its atmosphere at a very high velocity and has a high, for space conditions, concentration of the particles. Some possible catastrophic consequencies of such a collision are discussed.

The ordinary hail is familiar to all. More often it does not bring any danger. Only severe hails, with hailstones exceeding 1 cm in size, may cause some damage, e.g. to break a flimsy roof, to damage sowings, to wound animals or a person. The peculiar property of the hail is a simultaneous action of a great number of rather small-sized particles at their rather high concentration. By this reason in the situation when one particle does not produce any negative effect, because of a very low probability to hit a vulnerable place, very many particles would produce such an effect for certain.

This article is devoted to description of a cosmic phenomenon similar, to some extent, the hail. Namely, we write about the interaction of a great number of small particles with the atmosphere of the Earth or another planet when the particles fly in at a very high velocity $\mathbf{v}_0$ (Fig. 1). The particles are not necessarily icy but with approximately the same concentration as in the ordinary hail.

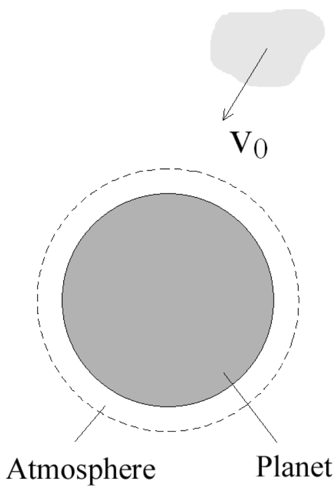

Fig. 1

First of all, there is a question whether such a phenomenon may take place in general. Evidently, that separate particles enter the atmosphere every day. Periodically the Earth passes through different meteor streams, e.g. the Leonids in November, the Perseids in August, the Geminids in December, etc. If the Earth gets in the central part of such meteor streams flares of thousands of meteors illuminate the night sky. They are so-called meteor showers. However even in this case the concentration of the entering particles is many orders less than in the case of the ordinary hail. And our goal is to investigate the case of the concentration typical for the hail.

In the nature such a high concentration of the particles may arise after total destruction of a large meteoroid entering the atmosphere, when the aerodynamic load exceeds the strength of the body. The body may split either into several large pieces or into numerous small particles depending on its composition and strength properties. In the last case the particles flow may resemble a hail. It is possible that a frail cosmic body may be scattered in dust under action of gravitational or electromagnetic forces even before the atmosphere entrance [1]. High enough concentration of small particles may also take place near a comet nucleus. If such a nucleus flies nearby a planet a great number of small dust particles may simultaneously enter the atmosphere.

In papers [2 – 5] we formulated the problems on intense interactions of large volumes of small particles with planets atmospheres. The interactions were called intense if the concentration of the entering particles was so high that the particles interacted with the atmosphere not individually but collectively. Approximately this is the usual concentration of the hailstones.

The most important distinction of the space hail from the ordinary one is its extraordinary high velocity. According to celestial mechanics cosmic bodies may enter the atmosphere with the velocities between the escape velocity (11.2 km/s for the Earth, 5 km/s for Mars) and the maximum relative velocity of the bodies belonging to the Solar System (approximately 70 km/s). The kinetic energy and the action of such a hail would be immensely higher. Moreover the space hail enters very rarefied layers of the atmosphere. Then the atmospheric density grows rapidly and the intensity of the interaction increases. So, the whole process strongly depends on the height over the planet.

A number of questions are of interest here. Whether the atmosphere can defend the planet from such a hail? How the process of interaction of the space hail will differ from the case of a separate particle or a body entering the atmosphere? How the interaction will depend on the size and the shape of the particles cloud, on the particles concentration and their sizes, substance, density and entrance velocity? How deep will the particles penetrate into the atmosphere? Will they totally evaporate or burn out in the atmosphere or some part of them, being decelerated, will fall on the ground? Will shock waves be formed in the atmosphere and what will be their intensity? Will they act on the ground and what may be the result of this action? What will be the temperature in course of the interaction process? Under what conditions the powerful light radiation is possible and how will it act on the ground? Are there any other mechanisms of the dangerous action on the planet? What are the limits of all dangerous actions?

The processes accompanying the entrance into the atmosphere of a separate small particle or a large body have been studied rather well by now. However, intense simultaneous interactions of a great number of small particles entering the atmosphere from the space have not been studied. Our investigations [2 – 5] were the first in which mathematical modeling and numerical experiment of this process were carried out and many of the above mentioned questions were answered.

In the following we describe briefly some results of these investigations.

The modeling of joint motion of the space hailstones and the atmosphere gas is carried out on the basis of the well known model of mutually penetrating continuum media. In addition to the gaseous medium of the atmosphere a “continuum” particles medium having no own pressure is considered. The particles are supposed to have negligibly small volume in comparison with the volume of the atmospheric gas. This assumption is always fulfilled for the interplanetary dust particles. As the particles substance we take ice of normal density like in the ordinary hail.

Different problems can be formulated depending on the scale and the geometry of the arising flow. In general case a particles cloud of an arbitrary shape and size is approaching a planet and its atmosphere (Fig. 1). If the cloud is relatively small the interaction process will proceed on a local scale. If the cloud is comparable with the planet the interaction will have a global scale and the whole planet atmosphere will be perturbed. The last case is most important for the problem of retaining the secure life conditions on the Earth.

Our calculations were performed for the Earth and Mars. We begin with the second planet.

The Martian atmosphere is highly rarefied at present. The atmospheric pressure and density at the planet surface are roughly 100 times less than on the Earth. However the space flights to Mars bring us more and more information that in the long past, 2 – 4 billions years ago, the Martian atmosphere was much more dense, like the Earth's, though consisted mainly of carbon dioxide (CO_2).

An evolutionary scenario explaining the loss of the Martian atmosphere was proposed [6]. According to it, at the early stage of the Martian evolution the balance of CO_2 in the atmosphere was due to, on one hand, supplying of carbon dioxide by intensive volcanic activity and, on the other hand, dissolution of CO_2 in water and formation of carbonate rock. It is Mars that has the biggest extinct volcanoes in the Solar System. As the volcanoes became less active the balance was violated, the atmosphere became more and more rarefied, the greenhouse effect diminished, the temperature lowered until the Martian atmosphere came to the present state. This theory is not accepted by all scientists because it can not explain all the facts. In particular, an 80 meter thick global layer of calcite must have been formed on the planet but it has not been detected yet. Moreover, there are some signs showing that the climate change on Mars was not the result of the slow and long evolution but happened rather quickly.

We suggest that Mars could have lost its dense atmosphere in course of a collision with a giant cloud of small particles. Such a cloud could have been formed in the vicinity of Mars as a result of a collision of two large asteroids. In the asteroid belt between the orbits of Mars and Jupiter there are enough of such asteroids. In the past there were even more such bodies and they had generally the greater size because, as is known, the processes of collision and fragmentation of bodies in the belt are permanent. By this reason the leading specialist in the field of meteor physics and small planets Prof. V.S.Getman called the asteroid belt the quarry of the Solar System [7].

Our hypothesis was supported by a direct numerical experiment that demonstrated that the loss of the planet atmosphere in course of such a catastrophic process was quite real. For example, in one of our calculations [5] the residuary mass of the Martian atmosphere (including the particles vapor) after the collision with a particles cloud turned out to be 1/3 of the initial mass. Thus, the loss of the essential part of the atmosphere has been confirmed to be possible.

A natural question arises whether such a catastrophe may happen with the Earth. Evidently, the general features of the particles cloud – planet atmosphere interaction would be for the Earth principally the same as for Mars. The distinction is only in greater dimensions of the planet, greater gravity force and escape velocity. Therefore, the loss of the Earth's atmosphere would be more difficult but still possible for some parameters of the approaching particles cloud. We also performed such computations.

However the detailed research of the interaction with the atmosphere of the particles cloud that can take away its considerable part is not of prime interest for the Earth. Unacceptable conditions for life on the Earth resulted from shock wave and light radiation actions on the ground would take place already for lesser total energies of the particles cloud when there would be no loss of the atmosphere.

And the last note in conclusion. In recent years people understand that the collision of the Earth with a large space body, a comet or an asteroid, is quite probable. This is the so called "asteroid danger". Thinking how to prevent it, some authors suggest that the approaching space body should be destroyed by a nuclear explosion. That means that the body would turn into a conglomeration of dust, gas, greater and smaller debris creating the rather concentrated flow of particles of different sizes. Those authors think that the collision of the Earth with such a cloud is less dangerous than with a single compact body. This is generally a big mistake according to our researches. In many cases the situation may only be deteriorated. The catastrophe may turn from local into a global one. This is why we decided to carry out the detailed investigations of the interaction process between a great number of small particles and a planet atmosphere, i.e. to find out how the hail from space would act and how dangerous it could be.

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Космический град опаснее астероида

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Ключевые слова и фразы: атмосфера; космос; облако; опасность; пыль.

Аннотация: Представлены некоторые результаты исследований ранее не изучавшегося природного явления – столкновения планеты с большим облаком частиц космической пыли («космического града») в условиях необычно высокой по космическим меркам концентрации частиц. Обсуждаются возможные катастрофические последствия такого явления.

Weltraumhagel ist gefährlicher als Asteroid

Zusammenfassung: Im Artikel sind einige Ergebnisse der Untersuchungen der früher nicht erlernten Naturerscheinung – des Zusammenstoßes des Planetes mit der großen Wolke der Kosmischstaubteilchen ("des Weltraumhagels") unter den Bedingungen der ungewöhnlich hohen Teilchenkonzentration dargestellt. Es werden die möglichen katastrophalen Folgerungen solcher Erscheinung besprochen.

La grêle cosmique est plus dangéreuse que l'astéroïde

Résumé: Dans cet article sont présentés quelques résultats des études du phénomène de la nature qui n'était pas exploré auparavant – collision d'une planète avec un grand nuage de poussière cosmique ("grêle cosmique") dans les conditions de la concentration extraordinairement grande selon les mesures cosmiques des particules. Sont discutées les conséquences catastrophiques possibles d'un tel phénomène.