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Asteroid and comet hazard: Identification problem of observed space objects with the parental bodies

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Abstract

This article focuses on the genetic identification of observed small cosmic bodies with alleged parental bodies; namely, comets, asteroids and meteoroid swarms. There is a problem of the upper D-value limit as a measure of proximity between the orbits of the bodies in the five-dimensional phase space (Southworth and Hawkins, 1963). In the study of genetic relationships of the comet and meteor complexes, the D value is usually taken as equal to 0.2 for all meteor showers. However, the upper D limit should be investigated for each meteoroid complex. For example, such investigation was performed for the Taurid meteor complex (Porubčan et al., 2006). In this paper, the upper D-criterion limit value was investigated for the Perseid meteor shower. The 1862 III Swift–Tuttle comet is its parental comet.

Keywords: Asteroid and comet hazard; Meteoroids; Meteoroid streams; Small bodies of the Solar system; The orbits evolution

1. Introduction

The Earth, like other planets and their satellites, experiences collisions with cosmic bodies. There are no fewer than 130 craters, with diameters of up to 250 km and different ages on the Earth's surface. The famous Meteor Crater in the USA has a diameter of 1200 m and a depth of 175 m. The crater was formed when the iron asteroid fell about 50,000 years ago. The size of this iron asteroid was equal to 60 m.

The standpoint finds more confirmation that the sudden dinosaur extinction was explained by the Earth's collision with a huge asteroid. A crater with a diameter up to 180 km, and age of about 65 million years was found near the Yucatan Peninsula in Mexico. The content of the iridium is hundreds times greater than the concentration in other layers found in the geological layers. It is known that the iridium is contained in large amounts in meteorites. Another global cosmic catastrophe may have occurred about 10,000 years ago and was the cause of widespread fauna extinction. These global cosmic catastrophes have become important factors in the life development on the Earth.

Under the influence of many cosmogenic factors the evolution of orbits of small bodies of the Solar system leads to the formation of meteoroid complexes (Sokolova et al., 2013). A set of criteria is used to find the genetic relationships. The comparison of theoretical and observational data will make it possible to determine the limiting values of D-criteria for each meteor stream and to use them successfully for genetic identification of the small bodies for solving various astronomical problems.

2. The use of the D-criterion method for the analysis of observational data of Tunguska event

More than 100 years passed after the mysterious explosion of an unknown body in the area of the

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Podkamennaya Tunguska River in Russia (30 June, 1908), but the phenomenon of the Tunguska meteorite continues to attract 'scientists' attention (Bronshten, 2000; Kundt, 2003; Gladysheva, 2007; Baldwin, 2008; Kolesnikov and Kolesnikova, 2010). It is expected that the composition of meteoritic material was utterly heterogeneous. The upper limit of the Tungus cosmic body's density was rated as 2.8 g/cm^3. Owing to the interaction with the Earth's atmosphere, the cosmic body disintegrated into fragments from 10^{-7} to 10^{-3} m in size, and it is known that most of the material was ejected into the upper layers of the atmosphere. However, the mystery of the Tungus nature is unsolved.

No craters or any meteorite fragments were found on the ground after the explosion of the Tungus object. A number of exotic hypotheses were caused by it: a meeting with body of antimatter; a small black hole; the explosion of a 'UFO', etc. The first scientific expedition under the direction of L.A. Kulick examined the impact area in 1927. The suggestion of the Earth's collision with a 50 m body of cometary origin is the most realistic today. The findings are based on eyewitness testimony and calculations within the mechanics and aerodynamics: 47% of testimonies of bolides flight described its structure in detail, marked out its core and tail ('lump flame', 'fireball' with a fiery, fiery white, pink and red tail 'broom'). Thus, most researchers agree that the Tungus bolides could not be a stone, iron-stone, or an iron asteroid, as there is a dark plume of smoke in the atmosphere during the combustion of such objects. It can be assumed that it was a body composed of ice water and hydrocarbon components, including methane. Intensive release of the cometary material mass occurred as a result of the atmosphere, and the body's sudden braking interaction, which led to the formation of clouds of burning mixture. A white stripe and haze were noticed which are left in the sky after bolide flight, and can be the result of water ice evaporation on heating the comet's nucleus.

The body fell apart into small fragments during the flight, and their burning was seen in the form of sparks or even 'red-hot' fragments. Eyewitness testimonies and no meteorite crater or debris on the ground led to the conclusion that the body exploded or disintegrated in the air. It was established that the zone of levelled forest occupied an area of some 2150 square metres and the felled trees' position was well-expressed in a radial direction.

The so-called 'Wire forest' (upright standing trunks without branches) has been detected in the middle of forest inrush for 3–5 km. Such destruction could be produced by both a concentrated and extended explosion. In the first case, estimating the air pressure speed in the air-blast that can cause the forest inrush calculated energy is equivalent to the charge capacity, which is equal to about 10 megatons of TNT. Burst altitude was estimated by the size of 'Wire forest' area, and was about 6–10 km (Ben-Menahem, 1975). This inrush could also be produced by a ballistic-air blast from a flying body, which flew at large angles to the Earth's surface at supersonic speeds that broke down at a certain height and decelerated to the speed of sound (Korotkov and Kozin, 2000).

The hypothesis of the stone body, or falling coaly chondrite, is not confirmed because of the lack of the fragments in the landing place. This is despite the numerous expeditions and research that have been done in this area. The large stone body should feel crushing process during flight in the atmosphere, under the influence of pressure on its frontal surface. Indeed, it is stone and carbonaceous meteorites which are found most often. The Tunguska bolide remained an unidentified object, presumably of cometary origin. It is extremely difficult to get some information about the phenomenon, which was observed 100 years ago. Therefore, this amazing event will remain a mystery of the twentieth century.

The probability of the Earth's collision with a cosmic body is about once in a 100 years. At the turn of the 20th and 21st centuries there was a serious reassessment of the possibility of the Earth's collision with the small bodies of the Solar system. This is a result of the accumulation of fundamental knowledge about the population of the Earth, surrounded by small bodies, and their physical and dynamical evolution. The spatial density of small bodies in the Solar system passing through the near-Earth space depends on their mass, and is shown in Fig. 1 (Bagrov et al., 2003).

Large sized meteoroids (10–100 m), called 'inasans', have low brightness and most visible velocity, as well as an uncertainty of direction of their arrival. Therefore, small bodies of this class are difficult to detect by telescope. There are two main options for exposure to a dangerous space object: the object's destruction; or a change in its trajectory. In any case, the object must be detected as early as possible to achieve the goal. All found inasans belong to meteor showers, so the important task is to establish the link between a small body and its parent body, for studying its evolution and possible approach between these objects and the Earth.

3. Genetic identification of a meteoroid with a meteor shower

Genetic identification of a meteoroid with a meteor shower can be done in different ways. The way to compare the radiant is the most reliable when radiant coordinates of a meteor shower are known and radiation area is small; that is, for well-studied and relatively new meteor swarms.

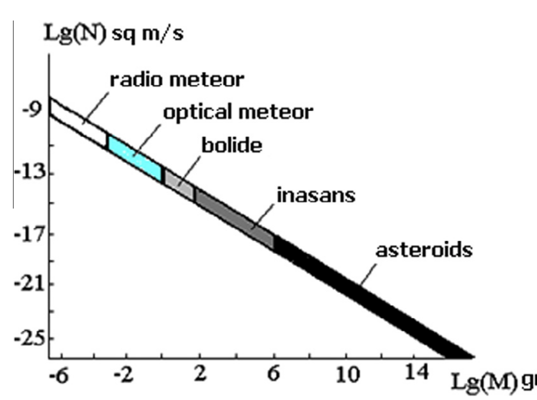

Fig. 1. Flux density of small bodies in the Solar system through near-Earth space, depending on their mass.