METEORITE PRODUCING FIREBALL STREAMS

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Meteorite producing streams (mainly of asteroidal origin) may contain large bodies, which are capable of causing great damage in the case of their fall on the Earth. Therefore the problem of meteorite producing streams is a part of a general multifaceted space hazard problem.
Analysis of the catalogue of 78 fireball streams (Terentjeva, 1990. *Asteroids, Comets, MeteorsIII, Sweden*) has revealed the streams which contain meteorite producing bodies among individual members of stream. There are 11 such fireball streams, and 6 of them (54%) are related to meteoroid streams.
As these meteorite producing streams are an object of special interest, the attention of observers and meteor researchers is called to this problem.

1 Introduction

A first service for registration of near-Earth (potentially hazardous) asteroids and comets (Space Watch) has been working since 1985. Now there are more than ten such services. Potentially hazardous asteroids or comets, as a rule, form associations and families, which may enter in meteoroid and fireball streams with meteoroids, having diameters of 1-10 m. It is currently believed that bodies with sizes of order of 10 m may bring local scale hazards. Those bodies can only be revealed occasionally, as they are very faint at 0.1 AU distance and almost always move with significant angular velocities. However, statistics of fireball and meteor showers, especially, related to asteroids and comets, can indicate, which orbits and orbit families along with their theoretical radiants can be sources of hazardous bodies. They should be given preference for effective monitoring by observers, with given theoretical directions of motion and calculated angular velocities.

The meteorite producing streams (mainly of asteroidal origin) may contain large bodies which are able to produce substantial destructions, when falling on Earth. Therefore, the problem of meteorite producing streams is a part of a more general problem of space hazard.

2 Research results

Having analyzed 78 fireball streams (Terentjeva, 1989, 1990), we revealed streams having meteorite producing bodies among individual members of the stream. There are 11 such fireball streams. Orbital elements of these streams are presented in Table 1, their orbits are shown on Figure 1. In the last column of Table 1 the number (by corresponding source) of meteorite producing fireballs in the stream is indicated. Since in the work by Z. Ceplecha (1978) in Table of 44 European network fireballs the numeration is missing we introduced ordinal numbers which are given in the last column of Table 1.

From considered 11 meteorite producing streams the two streams are especially remarkable. One is μ-Orids (No. 1, Table 1) which has produced the meteorite Tagish Lake (more precisely the meteorite shower) (Terentjeva, Barabanov, 2004). The possible range of initial mass seems to be 50-180 tons (Brown et al., 2001). Another stream, α-Comds (No. 21A, Table 1), has produced the Přibram meteorite with initial mass of 21500 kg (Ceplecha, 1978). The meteorite belongs to bodies of group I with greatest structural strength. Average density of bodies of group I is 3.7 g/sm^3. Meteorites Lost City and Innisfree belong to this group also. The group I corresponds to ordinary chondrites. Meteorite producing fireball from the stream η-Serds (No. 38, Table 1) is chondrite also. The stream ζ-Tauds (No. 72, Table 1) has three meteorite producing fireballs with initial masses M_∞ of 17000 kg, 240 kg and 100000 kg. In the remaining eight streams M_∞ ranges from 47 kg to 340 kg with the exception of the stream τ-Cetds (No. 50. Table 1) which includes a fireball with a mass M_∞=35000 kg.

Among 11 orbits of meteorite producing streams 5 orbits have aphelion q' located within the Main Belt of asteroids and 5 are located outside in the neighbourhood of orbits of Hilda type asteroids (with distance from Sun about 3.95 AU). Only one stream (No. 64, Table 1) with aphelion $q' \approx 1$ AU belong to Earth group.

Considering the link between meteorite producing streams and meteoroid streams we found that 6 streams from 11 streams (54%) are related to meteoroid streams (Table 2). Thus, all meteoroid streams related to these specific fireball streams are also meteorite producing streams.

It is necessary to add two streams to the found 11 meteorite producing fireball streams. First is meteoroid stream ι-Piscids (Terentjeva, 1966, No. 131), because a very bright fireball was caused by this stream. The fireball flew over Czech Republic and Poland on 2003 September 29 and produced a meteorite with mass of 400 g (Spurný, 2003). Report on this subject was presented by us on IX International conference "Near-Earth Astronomy-2015", August 31 – September 5, Russia, Terskol (Terentjeva, Barabanov, 2015). Paper is being prepared for publishing.

Second is found by us meteoroid stream of the large Chelyabinsk fireball on 2013 February 15. This stream we named Daytime Peg-Aquarids (Terentjeva, Bakanas, 2013). The large fireball produced the meteorite "Chelyabinsk". Mass of the largest fragment of this meteorite is 570 kg or more (Popova et al., 2013).

Other researchers may extend our list of meteorite producing streams considerably. We revealed 15 fireball streams which do not have a meteorite producing component, but they have massive meteoroid bodies with initial mass M_∞ of about 50 kg and more (Table 3, Figure 2). In this set of streams the streams are found with a larger variety of orbits. For example, one stream has aphelion $q' \approx 7.4$ AU which is located between orbits of Jupiter and Saturn. Orbital inclination i for three streams is 18˚, 28˚ and 30˚ (meteorite producing streams have inclination $i \leq 16$˚, Table 1). Less number of aphelion distances (6 from 15,

that is 40%) are located in the Main Belt of ateroids. The remaining streams have typical Apollo orbits with aphelion distances between the outer Main Belt border and the Jupiter orbit, that is $q \leq$3.8 AU – 4.8 AU, except for the stream, mentioned above.

In the four streams the fireballs are detected which belong to groups II and IIIB in Ceplecha and McCrosky classification. Bodies of group II have density of the order of 2.1 g/sm^3 and are possibly linked to carbonaceous chondrites (Ceplecha, 1978). The bodies of group IIIB have density of the order of 0.2g/sm^3. Many of fireballs consist mostly of porous comet matter and have such a low density.

Note that entrance velocities of meteoroid bodies in the atmosphere (for 11 streams from 15) are enclosed in the range of V_∞=14-26 km/sec and thus do not exceed presently adopted upper limit of entrance velocity for meteorite producing bodies in the atmosphere (Terentjeva, 1989a). And for all that massive meteoroid bodies with large initial mass M_∞ do not "penetrate" the Earth atmosphere. Of course, in reality different kinds of dependences work which are much more complex than generally considered as Ceplecha noted (1978). However, apparently we can assume that in a group of 15 fireball streams with massive bodies we deal with porous comet matter. Seven fireball streams from 15 fireball streams of this group (47%) are related to meteoroid streams (Table 3).

3 Conclusion

Due to the fact that meteorite producing streams are object of special interest the observers and researchers of meteors need to pay attention to the following.

1. One should compare the new extensive series of fireball observations, available now, with the meteorite producing streams described above, expanding hereby our knowledge about those fireball streams.

2. To complement these streams with new data about the presence of meteorite producing component in these streams and to find new meteorite producing streams.

3. It would be reasonable to organize an effective monitoring of meteorite producing streams.

Minor meteor showers seem unattractive for some observers of meteors due to their weak activity. But there were many cases when those “weak” showers produced unexpected fireworks of bright meteors and fireballs, and even created a surprise in the form of meteorite shower. It happened, for example, with fireball stream μ-Orids, which produced the meteorite Tagish Lake (see above).

Thus meteorite producing streams should always be in the zone of high attention of meteor researchers.

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