The existence of the groups of meteorite-producing sporadic fireballs and meteorites in cometary orbits

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The motivation and goal of research. Event of Chelyabinsk meteorite has shown that the meteoroids of decameters size also can be dangerous. Especially **the bodies of the small sizes from meters to decameters** on the Earth-crossing orbits on a time scale of a human civilization represent **the natural hazards because of the greatest probability of risk of collision with the Earth**. In present time the interest has increased to study the meteorite-producing fireballs similar Chelyabinsk bolide **to understand when and whence can arrive on the Earth the meteorites of such class.**

The possibility of existence of groups of meteorite-producing bodies which include meteorites Pribram, Benesov, Neuschwanstein, Park Forest, Kosice and Mason Gully, classified as ordinary chondrites was analysed in this Report. The main argument for existence of groups of meteorite-producing bodies is the existence of fireballs and meteorites with mutually similar orbits and of meteorite falls with a correlated day-of-fall.

Sources – IAU MDC of orbits (http://www.astro.sk/~ne/IAUMDC/Ph2003/database.html)
Meteoritical Bulletin Database. http://www.lpi.usra.eedu/meteor/metbull.php
SAO Nasa ADS Astronomy Query Form. http://adsabs.harvard/edu/abstract service.html
and the other published sources have been used to select sporadic potential meteorite-dropping fireballs brighter than magnitude -7 -- -8 with currently similar orbits to meteorites.

Criteria for selection sporadic potentially meteorite-dropping fireballs:

initial velocity $V_\infty \leq 30$ km/s; terminal velocity $V_e \leq 10$ km/s;
terminal altitude $H_e \leq 30$ km; terminal mass m_e > several tens of grams.

One more important criterion have been used for selection is type of ablation which depend on the physical characteristics of the bolide: bulk density, structural strength, and manifest themselves in the features of the luminiscence that is visible on the light curve.

On the base of this criterion in the time of 1.5-2 monthly periods of appearance of six known ordinary chondrite meteorites the potentially meteorite-producing fireballs were selected using the sources as above.

In Fig. 1 the histogram of the annual occurrence of meteorite-dropping sporadic fireballs of asteroidal (green line) and cometary (blue line) origin and meteorites with known fall dates (red line) with 2-day bins is shown. As one can see, the **annual occurrence shows six major and two minor increases in fireball activity within a year**.

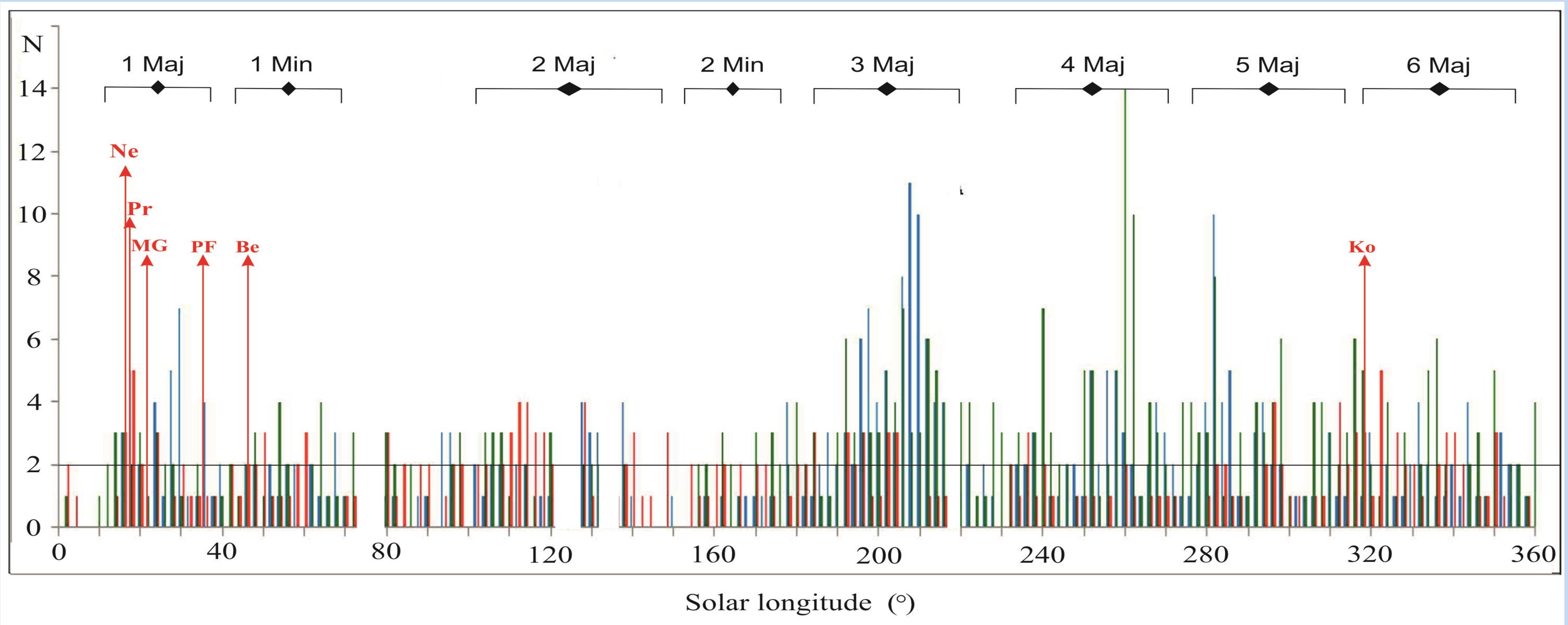


Figure 1. The red arrows indicate the dates of appearance of six meteorites with known orbits and one can see, the dates of them fall within the specified periods of annual occurrence.

In this presentation we considered a possible link between meteorites Pribram, Benesov, Neuschwanstein, Park Forest, Kosice and Mason Gully with comet-like orbits ($T_J \lesssim 3.1$) of Jupiter family and meteorite-producing fireballs.

The **association of objects in groups** was established on the base of analyzing their orbits, using proximity criteria D_{Dr} and D_{SH} as a means of estimating the degree of similarity between the orbits of the studied objects. The threshold value Dc =0.2 for D_{SH} – similarity functions and the threshold value Dc = 0.1 for D_{Dr} –similarity function was selected, which should reduce the number of chance coincidences from the compiled set of fireballs.

A group of meteorite-producing meteoroids is a group of meteoroids and of each specified meteorite which contributed to the final mean orbit. In result six identified groups comprising a total of 95 meteorite-producing meteoroids associated with six known ordinary chondrites were found.

The orbits of the studied bolides were classified as comet-like on the basis of Tisserand parameter: $T_J = a_J/a + 2 \cos I \times [(a/a_J)(1-e^2)]^{0.5}$, where a and a_J are the semi-major orbital axes of the bolide and Jupiter, respectively; i, e are inclination and eccentricity of the orbit. For cometary type orbits $T_J \lesssim 3.1$, for asteroid orbits $T_J > 3.1$

The physical properties of studied meteorite-producing bolides.

The calculated value of the aerodynamic pressure at the height of maximal brightness and terminal flare used to estimate the bulk density of the meteoroids. In result a value of bulk densities of meteoroids in these six groups were obtained.

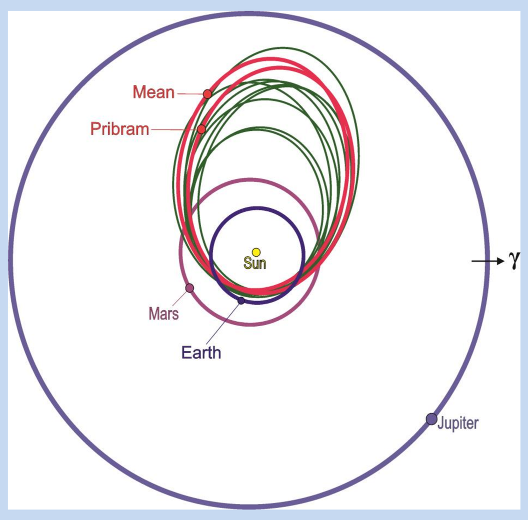
The bulk density ρ_m of bolides lie in the next interval: in group of meteorite Pribram ρ_m = 900 ÷ 1750 kg/m^3, in group of meteorite Benesov ρ_m = 700 ÷ 1400 kg/m^3, in group of meteorite Neuschwanstein ρ_m = 1150 ÷ 2050 kg/m^3, in group of meteorite Park Forest ρ_m = 750 ÷ 1900 kg/m^3, in group of meteorite Kosice ρ_m = 1050 ÷ 1250 kg/m^3 and in group of meteorite Mason Gully ρ_m = 1050 ÷ 2000 kg/m^3

Table 1 shows the data of the mean orbits of six groups of meteorite-producing meteoroids and known meteorites ordinary chondrites with similar orbits according to the D_{SH} and D_{Dr} criterions ($D_{SH} \lesssim 0.2$, $D_D \lesssim 0.1$).

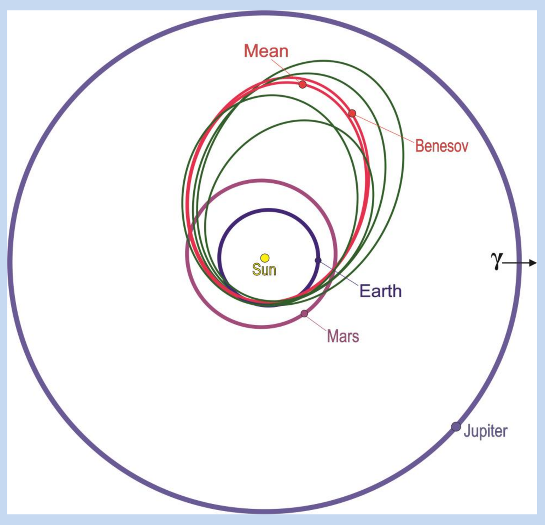
Table 1. Data for 6 groups of known meteorites and mean orbits of linked bolides(J2000.0).

name (n)	α_R (°)	δ_R (°)	V_g km/s	q au	a au.	e	i (°)	ω (°)	Ω (°)	Dd	Dsh
Group of meteorite Pribram											
Mean (7)	184.4	-4.5	19.8	0.795	2.495	0.664	3.8	58.3	205.9	0.00	0.00
Pribram	192.3	17.5	20.9	0.790	2.401	0.671	10.5	241.8	17.8	0.05	0.15
Group of meteorite Benesov											
Mean (13)	224.0	40.6	19.3	0.948	2.360	0.588	20.4	211.6	53.4	0.00	0.00
Benesov	227.6	39.9	21.1	0.925	2.483	0.627	23.7	218.4	47.0	0.04	0.08
Group of meteorite Neuschwanstein											
Mean (12)	183.6	-6.9	19.9	0.798	2.430	0.665	4.5	240.2	21.0	0.00	0.00
Neuschwa-nstein	192.3	19.5	21.0	0.793	2.401	0.671	11.4	241.2	16.8	0.04	0.13
Group of meteorite Park Forest											
Mean (19)	173.6	10.8	19.3	0.830	2.486	0.663	5.1	233.6	6.5	0.00	0.00
Park Forest	171.8	11.2	19.5	0.811	2.530	0.680	3.2	237.5	6.1	0.03	0.09
Group of meteorite Kosice											
Mean (18)	113.0	23.1	17.0	0.884	2.564	0.652	3.4	219.9	327.3	0.00	0.00
Kosice	114.3	29.0	15.0	0.957	2.710	0.647	2.0	204.2	340.1	0.05	0.09
Group of meteorite Mason Gully											
Mean (20)	151.9	10.9	16.8	0.905	2.455	0.624	5.3	41.1	176.8	0.00	0.00
Mason G.	148.4	9.0	14.6	0.982	2.556	0.616	0.9	19.0	203.2	0.05	0.12

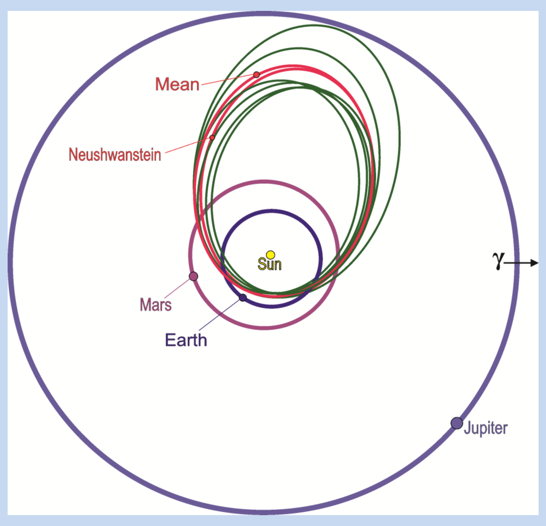
Figure 2. The projection onto the ecliptic plane the orbits of six groups of meteorite-producing fireballs and known meteorites ordinary chondrites



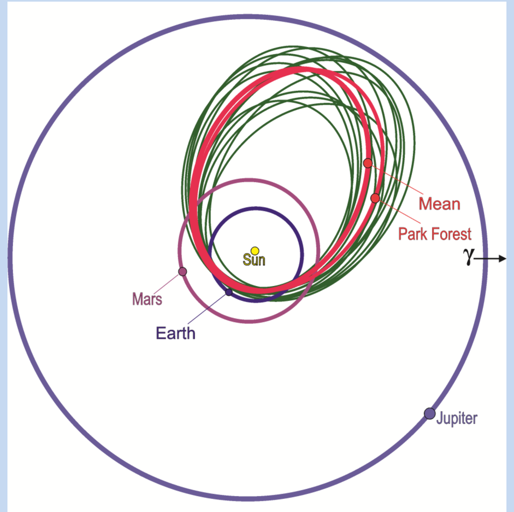
Group of Pribram



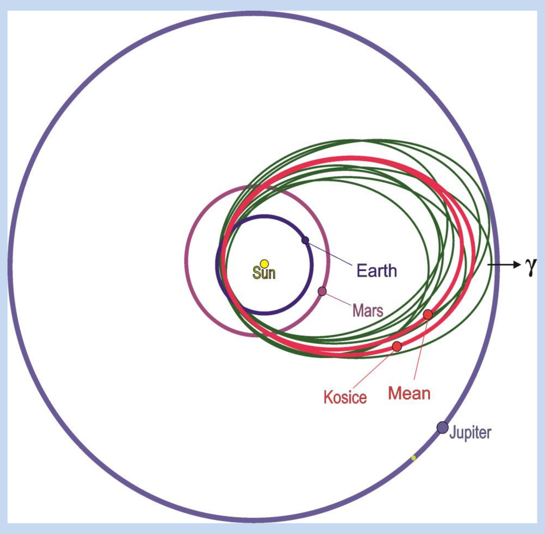
Group of Benesov



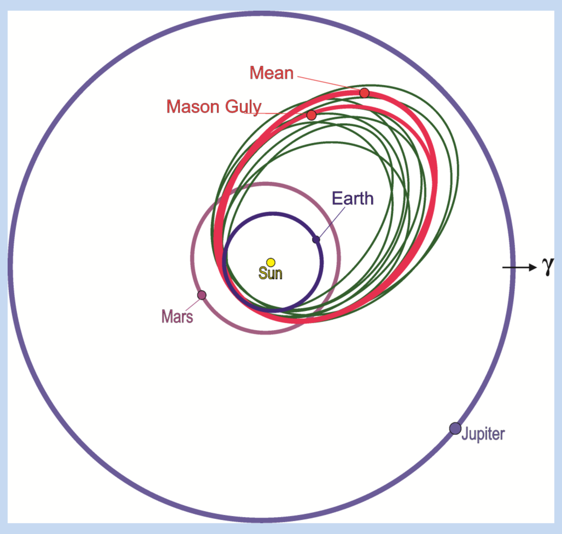
Group of Neuschwanstein



Group of Park Forest



Group of Kosice



Group of Mason Gully

Conclusions: In solar system especially the bodies of the small sizes (50 – 100 m) on the Earth-crossing orbits on a time scale of a human civilization represent the natural hazard because of the greatest probability of risk of collision with the Earth. The identified six groups of meteorite-producing meteoroids and known ordinary chondrites may still contain large meteorite-producing bodies. In practical terms, this can serve as an incentive for purposeful monitoring of the indicated groups of the meteorite-producing fireballs in the identified periods of increased fireballs and meteorites activity by means of both of land fireball network and space tools established on orbital satellites that is important for the prevention of danger for the Earth.