The Trajectory, Orbit and Preliminary Fall Data of the JUNE BOOTID Superbolide of July 23, 2008

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Abstract The results of the atmospheric trajectory, radiant, orbit and preliminary fall data calculations of an extremely bright slow-moving fireball are presented. The fireball had a -20.7 maximum absolute magnitude and the spectacular long-persistence dust trail (Fig 1 and 2) was observed in a widespread region of Tajikistan twenty eight minutes after sunset, precisely at $14^h\ 45^m\ 25^s$ UT on July 23, 2008. The bolide was first recorded at a height of 38.2 km, and attained its maximum brightness at a height of 35.0 km and finished at a height of 19.6 km. These values are very much in line with other well-known fireballs producing meteorites. The first break-up must have occurred under an aerodynamic pressure P_{dyn} of about 1.5 MPa, similar to those derived from the study of atmospheric break-ups of previously reported meteorite-dropping bolides. Our trajectory, and dynamic results suggest that one might well expect to find meteorites on the ground in this case. The heliocentric orbit of the meteoroid determined from the observations is very similar to the mean orbit of the June Bootid meteor shower, whose parental comet is 7P/Pons-Winnecke (Lindblad et al. 2003). If the parent was indeed a comet, this has implications for the internal structure of comets, and for the survivability of cometary meteorites.

Keywords fireball · meteoroid · atmospheric trajectory · radiant · orbit · fall data

1 Introduction

On July 23, 2008 at $14^h\ 45^m\ 25^s$ UT, two minutes after sunset, an extremely bright slow-moving fireball and the spectacular dust trail that it left behind were witnessed by numerous casual witnesses in a widespread region of Tajikistan. The area from which it was seen was within a radius of about 300 km. The sky in the area of the fireball was completely clear. The event was bright enough to be recorded by video and photo cameras, and, therefore, the time of the fireball passage is reliable derived from these observations. The intensity of the flash was so great that at about 100 km from the epicenter it was possible to be noticed by persons through the windows inside rooms. The majority of the eyewitnesses agree that suddenly the fireball became very bright. Some observers reported intense sounds, such as "cracking" and "thunder" just after the fireball appearance. A sonic boom probably associated with the bolide fragmentation at the height of the brightest flare was heard as far as 100 km away from the burst location. Many witnesses watched the resulting dust trail, which was perceptible for about 20 minutes

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Figure 1. The trail of the July 23, 2008 fireball from HisAO (Tajikistan). The photograph by U. Hamroev was taken at 14:45 UT

Figure 2. The trail of the July 23, 2008 fireball from Vose (Tajikistan). The photograph by M. Ahmetzyanov was taken at 14:58:58 UT

and was expressive distorted by the atmospheric winds. The trail of the fireball was very bright exhibiting a blue-white and on the end orange-red colors. The fireball was observed by a visible-light satellite system which detected a brightest path of fireball light. The total radiated energy was 2×10^{11} J, which is equivalent to a total released energy of about 0.05 kT (Brown 2008). The fireball's flare reached an absolute magnitude of -20.7 putting it in the superbolide category. One day after the event we interrogated inhabitants and a few witnesses have furnished numerous photographs of the dust trail of which two double-station photographs (baseline of 11.3 km) fortunately were taken immediately after the flight of fireball, showing clear references for being calibrated. The trajectory of the fireball was in fact photographed only during the later stages of its path. The terminal point of the fireball can be seen close to the western horizon.

2 Data Obtained

On the basis of two available double-station records (baseline of 11.3 km) the astrometric calibration of the fireball apparent trajectory in reference to the stars was made following the standard procedure and method described in (Katasev 1966). The procedure to obtain the astrometric measurements was based on the use of a Zeiss Ascorecord device. Measuring the rectangular coordinates of the positional stars and any feature point (beginning, terminal, and all flares and depressions) on the fireball trail, such measurements were converted to equatorial coordinates by using the astrometric method of the METEOR software package developed by the Meteor department (Institute of Astrophysics, Tajikistan). As a result of the astrometric measurements we were able to determine the fireball atmospheric trajectory, radiant, velocity, and orbit. The exact duration of the fireball was known from the data of a visible-light satellite system (Brown 2008). The fireball was first recorded at a height, H_b of 38.2 ± 0.5 km when the velocity, v_b was 14.3 ± 0.5 km/s. The fireball traveled a 19-km observed luminous trajectory and terminated its light at a low altitude H_e of 19.6 ± 0.5 km when the fireball decelerated to 5.8 ± 0.5 km/s. The slope of the trajectory was extremely steep - the zenith distance of the radiant was only of about 10° and the difference between the beginning and the terminal height was 18.6 km. The brightest flare was near the beginning of the trajectory at the height $H_{max} = 35.0 \pm 0.5$ km when the first break-up must have occurred under an aerodynamic pressure P_{dyn} of about 1.5 MPa. At the heights of other two small flares the aerodynamic pressure was 2.9 MPa and 3.1 MPa respectively. The apparent radiant was in Bootes, which suggest that the bolide belongs to the J.Bootid meteor shower. The resulting data on the atmospheric trajectory and coordinate of radiant, calculated by software METEOR are given in Table 1 and Table 2.

Table 1. Atmospheric trajectory data

	Beginning	Maximum light	Terminal
Velocity (km/s)	14.3 ± 0.5	13.1 ± 0.5	5.8 ± 0.5
Height (km)	38.2 ± 0.5	35.0 ± 0.5	19.6 ± 0.5
Abs. magnitude	-	- 20.7	-

Table 2. Radiant data

Radiant (J2000.0)	Observed	Geocentric	Heliocentric
α_R (deg)	221.83 ± 2.1	219.52 ± 2.1	-
δ_R (deg)	+32.40 ± 2.1	+30.95 ± 2.1	-
initial velocity v_∞ (km/s)	16.0	11.6	38.5

In order to obtain an accurate orbit, it is necessary for the fireball to be observed from multiple stations. In spite of the presence of only two records of the 23 July, 2008 fireball, the resulting data have a good accuracy. The initial (pre-atmospheric) velocity, $v_\infty = 16$ km/s was used for the meteoroid orbit computations. The resulting elements of the heliocentric orbit for the equinox 1950.0, calculated by software METEOR are given in Table 3.

Table 3. Orbital data

Orbit (J2000.0)	
Semimajor axis (AU)	3.32
Eccentricity	0.694
Perihelion distance (AU)	1.015
Aphelion distance (AU)	5.624
Argument of perihelion (deg)	176.76.
Ascending node (deg)	119.709
Inclination (deg)	11.95°

These orbital results were also tested by using the software of the Spanish Fireball Network (SPMN). It is remarkable that the computed orbit is very similar to the mean orbit of the June Bootid meteor shower (Lindblad et al. 2003). Both the *D*-criterion of Southworth and Hawkes (Southworth and Hawkes 1963) and Drummond (Drummond 1981) were applied to the obtained orbit ($D_{SH} = 0.114$ and $D_{Dr} = 0.082$). The meteoroid, with a mass of about 24 tons and a kinetic energy, possible in the order of 0.5 – 0.6 kt (personal communication Dr. O. Popova) entered the Earth's atmosphere with velocity of about 16 km/s. Penetrating deeply into the atmosphere, the aerodynamic pressure increased progressively on the front part of the body. At a height of 35 km the pressure on the surface reached 1.4 MPa causing the fracture of the body, so its mass started to break and crumble. Among the relatively few documented cases of collisions with bodies of such a great mass, this is a remarkable event because the body, probably of cometary origin, penetrated deeply into atmosphere and probably dropped meteorite. We hope to have the chance of recovering meteorites from this event occurred over an inhabited region.

3 Data of Dark Flight

The dark flight was simulated by using the standard procedure described in (Ceplecha 1987). The deceleration at the terminal point of the trajectory obtained from the estimated values of fireball velocity vs. height was -7.6 km/s^2, with a trajectory inclination of about 80º. The simulation was performed by taking into account the modeled atmospheric conditions (provided by the British Atmospheric Data Center) with a software package developed by the Spanish Meteor Network (SPMN) which uses a standard Runge-Kutta calculation procedure. Spherical shape was assumed and a value of the drag factor at the terminal point of 0.58 was used. Under these conditions, the terminal mass of the meteoroid, which depends on its density, would vary from 1.5 ± 0.3 kg (d = 3.7 g/cm^3) to 4.2 ± 0.3 kg (d = 2.2 g/cm^3). Most of the surroundings near of the impact area are covered by agricultural fields, without stones or rocks that would complicate meteorite searches, as the soil consists basically of clay. Thus the favorable circumstances of an almost vertical fireball trajectory and favorable countryside give a hope of successful search of the meteorite. At present, the search of additional and more detailed data is in progress and expeditions to the impact area will be organized in short in order to try to find the meteorite.

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