ANALYSIS OF A LARGE METEORITE-DROPPING FIREBALL FROM THE APOLLO NEA FAMILY.

N.A. Konovalova[1], J.M. Madiedo[2, 3] and J.M. Trigo-Rodriguez[4]. [1]Institute of Astrophysics of the Academy of Sciences of the Republic of Tajikistan, Bukhoro, str. 22, Dushanbe 734042, Tajikistan, nakonovalova@mail.ru. [2]Facultad de Ciencias Experimentales, Universidad de Huelva, Huelva, Spain, madiedo@uhu.es. [3]Departamento de Fisica Atomica, Molecular y Nuclear. Universidad de Sevilla. 41012 Sevilla, Spain. [4]Institute of Space Sciences (CSIC-IEEC). Campus UAB, Facultat de Ciències, Torre C5-p2. 08193 Bellaterra, Spain.

Introduction: The continuous monitoring of the night sky provides additional information on the origin of meteor and fireball events. The analysis of asteroidal and cometary meteoroids can give important information about the physical properties of these particles and also about the mechanisms of ablation of meteoroids in the Earth's atmosphere. The information that can be extracted from multi-station observations not only refers to the determination of radiant and orbital parameters, but also gaining insight on the photometric behaviour of fireballs during their atmospheric interaction. Two of the meteor observing stations operated by the Meteor Patrol of the Hissar Astronomical observatory (Tajikistan) and Kipchak station located 32 km from the base point simultaneously imaged a slow moving bright fireball of absolute magnitude -9.5±0.3 on August 5, 1980. The analysis of this event is presented here.

Methods: The photographic double-station records of the fireball designated 800676 were taken by meteor small-cameras MK-25 equipped with Uranus-9 (D/f = 1/2.5, f = 250mm) lenses which take one exposure per hour. These systems can record meteor trails as faint as mag. +1 and brighter. Type 22 photoplate was used in meteor observations, the negative size was 19×19 cm covering an area of the sky measuring approximately 40º ×50º. The astrometry and photometry of pictures taken by our meteor cameras is usually determined by a standard method described in [1]. The Meteor Patrol of the Hissar Astronomical observatory consists of six wide-field cameras equipped with a rotating shutter making 25 turns per sec. to measure the velocity. On the basis of these photographic records we obtain basic information about the exact time of the event, the fireball atmospheric trajectory and heliocentric orbit as well as the light curve and pre-atmospheric photometric mass of the fireball.

Results and discussion: We present here the atmospheric trajectory, radiant and heliocentric orbit of a slow moving fireball of absolute magnitude -9.5, recorded on August 5, 1980 at 16h 29m 28s UT during a systematic long-term observation photographic program [2]. The luminous trajectory of the fireball started at an altitude of 77.2±0.1 km and after a 50.4 km long flight ended at 33.1±0.1 km. The elevation angle of the atmospheric trajectory to the Earth's surface was of about 70º. The stations from where the bolide was photographed were not far from its trajectory (station HisAO about 150 km and station Kipchak about 200 km) and also the bolide was recorded about 60º at the horizon, therefore the position of the luminous trajectory in the atmosphere is very reliable. The maximal standard deviations for any measured point on the meteor trail on both meteor stations is 12.8 and 14.4 arc sec, which is accurate enough to obtain reliable data. The atmospheric trajectory and radiant data of this bolide are shown on Tables 1, 2.

Atmospheric data			
	Beginning	**Max. light**	**Terminal**
V (km/s)	16.5±0.1	16.3±0.1	10.6±01
H (km)	77.2±0.1	57.6±0.2	33.1±0.1
Abs. mag.	-0.3±0.2	-9.5±0.3	-3.8±0.2

Table 1. Atmospheric trajectory data for the 800676 fireball described in the text.

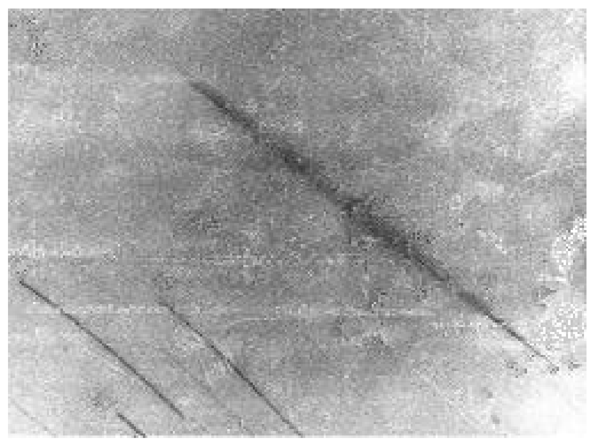

Figure 1. The 800676 fireball imaged from HisAO.

The determination of velocity and deceleration was difficult since the fireball was slow and very bright. Therefore we could measure time marks only in the third final part of luminous trajectory where breaks were distinguishable down to 33.1 km. The preatmospheric velocity was calculated from the velocities measured along the meteor trail using the formula $V(t)=b + ce^{kt}$, where $b=V_{\infty}$ [1]. It was found that the meteoroid entered the atmosphere with a velocity of 16.6±0.1 km/s and decelerated to the final value of 10.6±0.1 km/s. The deceleration of the fireball 800676 during its flight is small and this directs on the absence of the essential disruption of the body on ensemble of big fragments. From the time of the fireball occurrence, initial velocity, the position of the radiant and the heliocentric orbit were computed. The orbital parameters of this bolide are shown on Table 2.

The light curve of the fireball 800676 was obtained from the analysis of the photo picture. Fig. 1 reveals the peculiar photometric behaviour of this fireball. The light curve is smooth without strong flares which could point to sudden fragmentation of the body. The maximum absolute (100 km distance) brightness of -9.5±0.3 magnitude was reached at an altitude of 57.6±0.2 km. This curve was employed to calculate the initial mass of the meteoroid of ~24.9 kg was obtained. In this case the luminous efficiency is given by $\tau=\tau_0 V^n$, where the values n=1.0±0.15 and $\tau_0=1.0\times10^{-19}$ (in c.g.s. units) were found to apply to bright meteors imaged with small meteor cameras [3].

Radiant data (J2000.0)				
	Observed	Geocentric		Heliocentric
R.A. (º)	308.3±0.2	-		-
Dec. (º)	31.5±0.2	-		-
V_∞ (km/s)	16.6±0.1	12.2±0.1		30.7±0.1
Orbital data (J2000.0)				
a(AU)	1.1±0.1	**ω (º)**		270.3±0.1
e	0.28±0.01	**Ω (º)**		133.653±0.006
q(AU)	0.791±0.001	**i (º)**		17.9±0.5
Q(AU)	1.41±0.2			

Table 2. Radiant and orbital data for the 800676 fireball described in the text.

Dark flight and impact position: To simulate the dark flight we used our AMALTHEA software, which follows the procedure described in [4]. Spherical shape for the meteoroid was assumed. The zenith angle of the trajectory was 71.8º, and the deceleration at the terminal point, calculated from the estimated values of fireball velocity vs. height, was -8.5 km/s^2. On the other hand, a value of the drag factor at the terminal point of 0.58 was used. Under these conditions, the terminal mass of the meteorite would vary from ~90 g (for a density of 3.7 g/cm^3) to 240 g (for d = 2.2 g/cm^3).

Parent body: We have employed our ORAS (ORbital Association Software) program to find the likely parent body of the meteoroid [5]. Thus, by using the Southworth and Hawkings criterion two candidates were obtained. These were NEOs 1999CV8 (D_{SH}=0.10) and 2001DF47 (D_{SH}=0.12). A numerical integration of the orbital parameters backwards in time has been performed in order to test the link between the fireball and these two NEOs. The integrations were performed using the Mercury 6 software [6]. The gravitational fields of Venus, the Earth-Moon system, Mars, Jupiter and Saturn were considered. The orbits were integrated back for 100,000 years. The results are shown in Figure 2, where the evolution of the D_{SH} vs. time is plotted. For both NEOs, D_{SH} remains below 0.4 for over 70,000 years. Besides, our analysis reveals a dynamic link between both NEOs, which would imply a common origin for these two bodies.

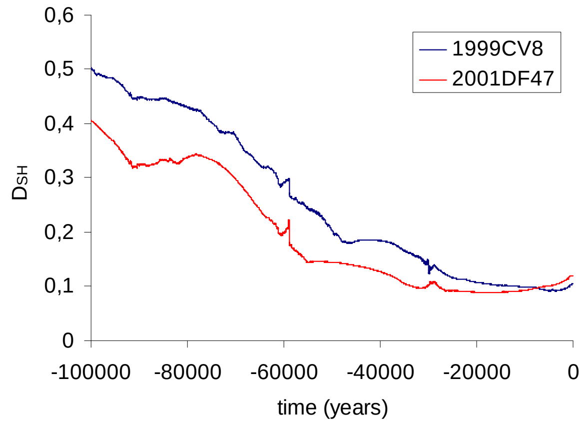

Figure 2. Evolution of the D_{SH} criterion calculated by comparing the orbits of the meteoroid and NEOs 1999CV8 and 2001DF47.

Conclusion: The analysis of the mag. -9.5±0.3 slow moving fireball studied here has allowed us obtaining its atmospheric trajectory, radiant and heliocentric orbit. Additional information on the luminosity and the pre-atmospheric photometric mass was also obtained. According to the dynamic and luminosity behavior in the atmosphere, meteoroid 800676 was dense and strong enough to be produced by a stony material comparable with ordinary chondrites. Tisserand parameter T_J = 5.57 and, so, an asteroidal origin of meteoroid 800676 is likely. The meteoroid before its collision with the Earth orbited the Sun on an elliptic orbit with the aphelion in the region of Near Earth's Asteroids (NEAs). Such kind of heliocentric orbit is quite usual for fireballs that penetrate deep into Earth's atmosphere producing meteorites [7].

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