THE "VALEC" FIREBALL AND PREDICTED METEORITE FALL

Z. Ceplecha and P. Spurny

Astronomical Institute of the Czechoslavak Academy of Sciences
Ondrejov Observatory, Czechoslovakia

After 22 years of continuous operation of the Czechoslovak part of the European Network for photographing fireballs, we succeeded in taking pictures of an object with a luminous trajectory below a height of 20 km (Ceplecha and Spurný, 1984). On Aug. 3, 1984, at $21^h05^m53^s$ UT, seven Czech stations photographed this slow-moving fireball, which traversed 94 km of luminous trajectory in 9.2 seconds and terminated its visible flight at a height of 19.1 km. The computed dark-flight trajectory intersected the surface close to Valec, a small village 40 km west of Brno. The "Valec" fireball was not only the lowest fireball photographed in our European program, but also the lowest photographed fireball ever. The only exception, the Príbram fireball photographed in the year 1959, terminated its luminous trajectory at a height of 13 km, but the photographs of its trajectory were taken only down to 22 km, where the trajectory went off the field of view of the camera system. The "Valec" fireball was photographed by fish-eye cameras with Zeiss-Distagon objectives f/3.5, f=30 mm, field of view 180°. The positional precisions of all our records were within the range of 1 to 2 minutes of arc. The closest station to the fireball trajectory was only 41 km from it and its picture (Fig. 1.) shows 109 measurable breaks spaced by about 0.08 seconds. Our rotating shutter is close to the focal plane. All measurements on all photographic plates were done by J. Bocek and this activity comprised more than 1600 points to be measured using a Zeiss Astroecorder. All computations were done by the authors of this paper using the FIRBAL program, a set of almost 4000 Fortran statements (Ceplecha et al., 1979) run on an EC 1040 computer at the Ondrejov Observatory, which is our standard procedure used for every fireball photographed by at least two stations. We tried to get our results as soon as possible, to be ready for a meteorite search before the harvest season was over. The average computed mass at the terminal point, i.e., the predicted mass of the biggest meteorite, was 16 kg. This number is based on the dynamical data at the terminal point solely (velocities and decelerations). We also collected visual data from occasional observers and it became clear from them that, except for the main mass, about 10 fragments reached the surface.

The fireball was a slow moving object, which enhanced the probability of a meteorite fall. The luminous trajectory started at a height of 84 km over the Austrian town of Heidenreichstein and terminated at a height of 19.06 km over a point slightly east of Jaromerice and Rokytnou (Table 1). The absolute maximum brightness was almost -10 stellar magnitudes at a height of 54 km. The maximum of the light curve was very flat and the brightness stayed close to -9.5 magnitude in the height interval from 58 to 24 km. The initial velocity of 12.7 km/s changed only slightly down to the point of maximum brightness, where it reached 12.3 km/s. The initial photometric mass of about 380 kg changed only by 20 kg at this point with about 360 kg remaining. Thus the body was predetermined to penetrate very deeply and retain enough rest mass to reach the surface. At a height of

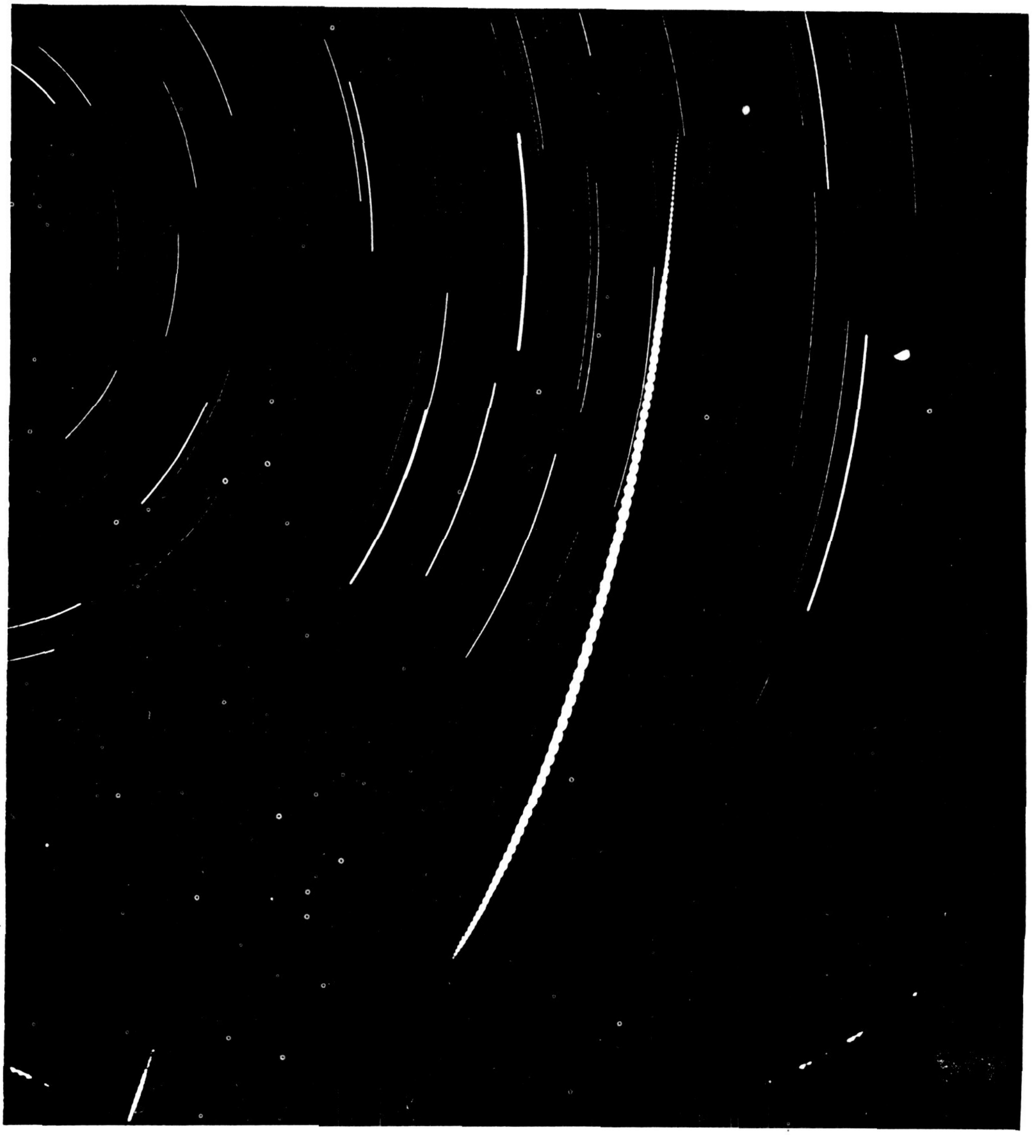

Fig. 1 Photograph of the "Valec" Fireball from station No. 15, Telc, by fish-eye Zeiss-Distagon f/3.5, f=30 mm, field of view 180°. The time marks (breaks on the fireball trail) are spaced by about 0.08 s. The curvature of the fireball trail is due to projection properties of the fish-eye objective. Direction of the flight: from up to down.

Table 1

	Beginning	Maximum Light	Maximum Deceleration	Terminal	Impact
Velocity km/s	12.69 ±.03	12.301 ±.014	5.58 ±.03	2.55 ±.08	0.088
Height km	83.79 ±.04	53.9 ±.2	22.47 ±.27	19.06 ±.28	0.5
Latitude N	48.8391° ±.0005°	48.971° ±.002°	49.111° ±.003°	49.1265° ±.0032°	49.1561° ±.0087°x)
Longitude E	15.1466° ±.0006°	15.520° ±.003°	15.922° ±.004°	15.9663° ±.0040°	16.0712° ±.0177°x)
Deceleration km/s^2	-0.032 ±.003	-0.275 ±.011	-3.04 ±0.03	-1.48 ±.03	-
Absolute Magnitude	-1.0 ±.2	-9.9 ±.4	-9.1 ±.4	-0.4 ±.2	-
Photometric Mass (terminal included) kg	377.	360.	102.	16.	16.
z_R	46.33° ±.11			46.94° ±.11	2.1°

x) standard deviations of the impact point include errors in the wind data

22.5 km, where the body reached its maximum deceleration of 3.0 km/s^2, it was still of -9.1 absolute magnitude. All the data on velocities, decelerations and masses are given in Table 2.

The "Valec" fireball terminated its luminous trajectory with velocity only 2.5 km/s. The rest mass of about 16 kg landed at 49.1561° ± 0.0087°N and 16.0712° ± 0.0177°E. Several criteria used for classification of the "Valec" fireball gave the same result: it was type I fireball, i.e. the same as Príbram, Lost City and Innisfree. Thus an ordinary chondrite was the most probable meteorite to be recovered. The penetration ability was somewhat larger than for type I, and an iron meteorite was not completely excluded since there is no experience with fireballs belonging to iron bodies.

Taking into account all uncertainties, we were reasonably sure that a multiple fall of meteorites followed the fireball and that the biggest piece was over 10 kg in mass. The complete footprint of all remnants was predicted as having a rather large area and is given in Table 3.

The radiant and orbit are given in Table 4. The orbit was almost in the ecliptic and the Earth met the body almost at its perihelion point, a little bit farther from the Sun than 1 A.U. The aphelion point was close to the 3:1 Kirkwood gap (WETHERILL, 1985). The orbit was typical for the meteorite fall published by WETHERILL and REVELLE (1981) and by HALLIDAY et al., (1984).

In the late summer of 1984, we searched for 3 weeks for meteorites in the predicted area, which mostly proved to be farmed land. Some less accessible places were left until autumn 1984 and spring 1985. Altogether a little over 2 km^2 were searched through, but no meteorites were found. We also instructed farmers and all interested people in the vicinity of the area that meteorites could be recovered. A small part of the area contained a water reservoir, but the probability that the main body fell there is rather low.

We used the "Valec" fireball to study the changes of ablation coefficient during the terminal parts of its luminous trajectory. We applied the method of PECINA and CEPLECHA (1984, 1985) and computed the "total ablation coefficient" for different height intervals. The result is in Fig. 2. From a height of 28 km to a height of 21 km the ablation coefficient increased 20 times (from 0.009 to 0.18 s^2/km^2) and seemed to level off at this high value. This change was associated with a sudden fragmentation shortly before the maximum deceleration point at a height of 28 km, and a possible fragmentation at a height of 26 km. Taking into account the terminal increase of the ablation coefficient, the major remnant should still have been quite large, of more than 6 kg, with the revised search area overlapping that actually searched. Considered against the statistical data recently published by HALLIDAY et al., (1984), it is no wonder that the search activities proved negative even in this very favorable case of a deeply penetrating fireball: on the average, about 10 searches were necessary for different fireballs with the same properties as the "Valec" fireball, to recover meteorites. But there is no doubt that all data on the "Valec" fireball are also data on a meteorite fall. (WETHERILL and REVELLE, 1981)

Table 2

Time s	Height km	Velocity km/s	Decleration km/s^2	Absolute Magnitude	Photometric x) Mass kg
0.00000	82.951	12.688±0.031	-0.034±0.003	-2.40±0.14	377
0.47999	78.760	12.669±0.029	-0.046±0.004	-2.83±0.13	377
1.03983	73.882	12.638±0.027	-0.065±0.005	-4.45±0.10	377
1.51974	69.712	12.602±0.025	-0.087±0.006	-5.35±0.12	377
1.99964	65.557	12.553±0.022	-0.118±0.007	-5.94±0.14	377
2.47954	61.422	12.487±0.019	-0.159±0.009	-7.45±0.21	376
3.03940	56.633	12.381±0.015	-0.225±0.011	-9.4 ±0.3	371
3.51928	52.569	12.255±0.013	-0.304±0.012	-9.9 ±0.4	358
3.99916	48.555	12.084±0.012	-0.410±0.013	-9.3 ±0.3	346
4.47906	44.609	11.855±0.015	-0.554±0.014	-9.3 ±0.3	335
5.03897	40.122	11.484±0.020	-0.786±0.014	-9.7 ±0.4	317
5.51898	36.310	11.108±0.005	-1.129±0.003	-9.6 ±0.4	300
5.99909	32.694	10.421±0.006	-1.758±0.003	-9.5 ±0.4	278
6.47931	29.450	9.409±0.006	-2.449±0.006	-9.5 ±0.4	246
7.03972	26.140	7.850±0.008	-2.954±0.014	-9.5 ±0.4	192
7.36000	24.521	6.896±0.012	-2.968±0.017	-9.3 ±0.4	155
7.60022	23.443	6.305±0.024	-2.97 ±0.03	-8.9 ±0.3	133
7.84045	22.469	5.58 ±0.03	-3.04 ±0.04	-9.1 ±0.4	102
8.00059	21.891	5.10 ±0.04	-2.98 ±0.04	-8.6 ±0.3	77
8.24082	21.074	4.41 ±0.05	-2.74 ±0.04	-8.1 ±0.3	36
8.40096	20.625	3.98 ±0.05	-2.53 ±0.04	-6.0 ±0.2	21
8.56108	20.220	3.60 ±0.06	-2.29 ±0.04	-3.60±0.10	17
8.64114	20.044	3.42 ±0.06	-2.17 ±0.04	-2.40±0.11	16
(9.11820	19.058	2.55 ±0.08	-1.48 ±0.03	-0.41±0.21	16)

x) terminal mass included

Table 3

Boundary of the whole strewn-field predicted.

Latitude N	49.168°	49.161	49.122	49.095	49.106	49.130	49.148°
Longitude E	16.089°	16.096	16.021	15.936	15.899	15.907	15.980°

Table 4

Radiant and orbit. (1950.0)

α_R	242.10° ± 0.16°	a	1.821 ± 0.016 A.U.
δ_R	17.17° ± 0.09°	e	0.443 ± 0.005
v_∞ (km/s)	12.74 ± 0.04	q	1.0135 ± 0.0001 A.U.
α_G	230.97° ± 0.22°	Q	2.63 ± 0.03 A.U.
δ_G	3.81° ± 0.19°	ω	184.78° ± 0.11°
v_G (km/s)	6.57 ± 0.07	Ω	131.2512° ± 0.0008°
v_H (km/s)	35.52 ± 0.06	i	3.92° ± 0.07°

Suffixes: R ... observed radiant, ∞ ... initial no-atmosphere velocity, G ... geocentric radiant and velocity, H ... heliocentric velocity.

Elongation from apex: geocentric radiant: 157.61° ± 0.23°
heliocentric radiant: 175.96° ± 0.07°

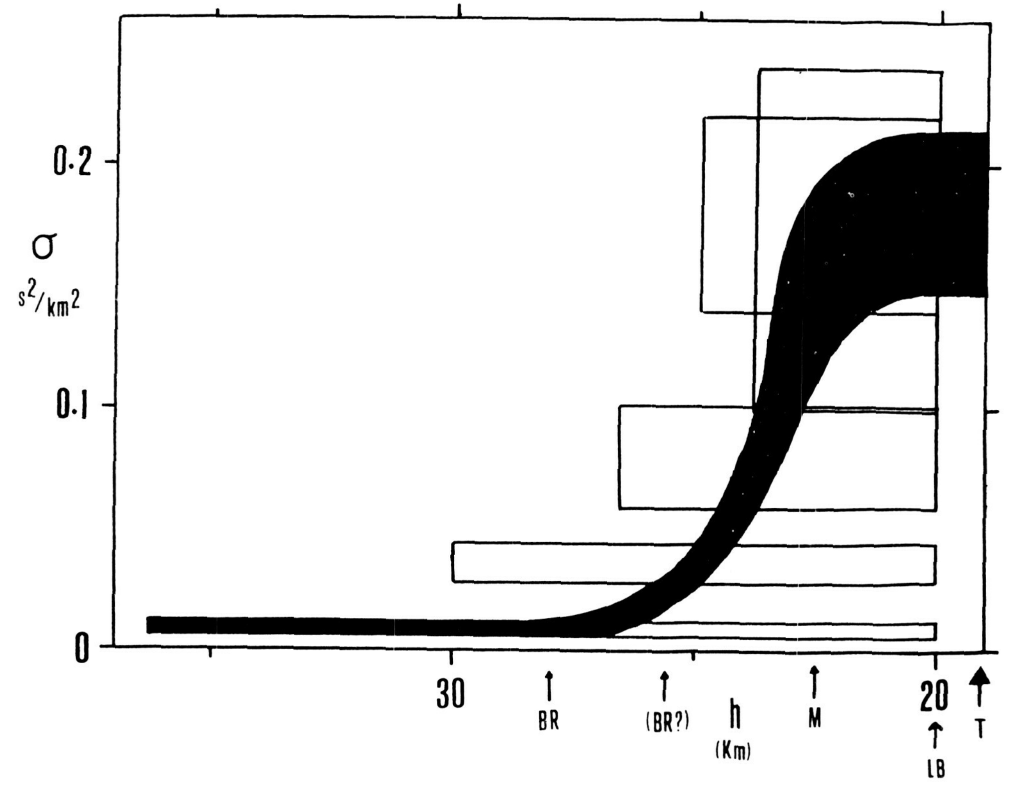

Fig. 2 The change of the ablation coefficient σ during the terminal portion of the "Valec" Fireball trajectory plotted against height h. Rectangles: area of standard deviations of solutions for total ablation coefficient σ in different height intervals. The thick curve covers the area of the most probable values of σ. BR...point of breakage, M...point of maximum deceleration, LB...last measured break, T...terminal point.

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