1994A&A...283..287C

Astron. Astrophys. 283, 287–288 (1994)

ASTRONOMY
AND
ASTROPHYSICS

Earth-grazing daylight fireball of August 10, 1972

Z. Ceplecha

Astronomical Institute of the Academy of Sciences of the Czech Republic, 251 65 Ondřejov Observatory, Czech Republic

Received 3 August 1993 / Accepted 18 August 1993

Abstract. A daylight fireball flew over the U.S. and Canada on Aug 10, 1972 with its trajectory tangential to the Earth surface and perigee at ≈ 58 km. The fireball body lost only a part of its mass and continued to move in a changed orbit. Unique observations by infrared radiometer tracking were acquired by Rawcliffe et al. (1974). The original paper and also Jacchia's paper (1974) on this fireball both contain several mistakes and misprints. This paper brings correct values and refers to my original paper (1979) for details. Especially, the extremely large mass of this meteoroid, frequently cited from Jacchia's paper, is not correct. New models of meteoroid ablation and fragmentation applied to this fireball yielded ≈ 5 m as the most probable size of the body at perigee. The maximum possible size of the body in its orbit at present is 10 m with a dark fusion crust on its surface. The body will come again close to the Earth sometime between 1997 July 30 and Aug 16, and the Earth will be at the same point 1997 Aug 11. But this is just a rough estimate from semimajor axis and its standard deviations. Solutions with incorporated gravitational perturbations are needed for any recovery efforts.

Key words: meteors: meteroids

1. Atmospheric trajectory

A very bright fireball attracted attention of an immense number of casual observers and photographers in the western United States and Canada in daytime on Aug 10, 1972. The trajectory of the body was unique in touching the Earth's atmosphere at slightly below a height of 58 km. The meteoroid lost only a part of its mass and continued to move in a changed orbit around the Sun. Unique observations of this fireball were acquired on board of a satellite by infrared radiometer tracking (Rawcliffe et al. 1974). Unfortunately Table 1 of this original paper contains several mistakes and misprints. Moreover, Jacchia's paper published in Sky and Telescope (1974) added another miscount in estimating the incoming mass of the body.

I exchanged several letters with Charlotte D. Bartky (1978), one of the coauthors of the original paper on infrared fireball tracking. In her quick and clear responses, she sent me not only the correct data corresponding to Table 1 of the paper in Nature, but also a smooth plot of the velocity changes during the entire observed trajectory. This enabled an independent check of the relative geographic positions and heights by integrating the dependence of velocity on time. A perfect match of both sets of data resulted. These correct values are given in Table 1. They were already given in my paper (Ceplecha 1979), where I published also the orbits before and after the encounter as they resulted from velocity changes observed during the atmospheric flight.

2. Mass

The most probable value of the mass of the body came out (Ceplecha 1979) within a range of 10^5 to 10^6 kg, much less than the quite unrealistic Jacchia's estimate. Jacchia (1974) evaluated the mass range from four thousands to a million metric tons (4×10^6 kg to 10^9 kg) using estimates of the fireball brightness. But the given masses did not correspond to the given brightnesses at all. Jacchia's computations must contain a numerical mistake of about two orders of magnitude: either he took an extremely low luminous efficiency, entirely inconsistent with anything published before (including also previous Jacchia's papers), or he made a mistake by 5 stellar magnitudes. With realistic luminous efficiencies and with bulk density of 3.7 g/cm^3, the photometric mass determined from the same magnitude estimates as Jacchia used would be 70 metric tons (70000 kg) for -15 maximum stellar magnitude of the object at a distance of 100 km, or 3000 metric tons (3×10^6 kg) for -19 maximum stellar magnitude at a distance of 100 km.

The authors of the infrared tracking (Rawcliffe et al. 1974) estimated 1000 tons (10^6 kg) from the recorded thermal radiation, but they assumed that the whole change of kinetic energy went into thermal radiation. Thus lower mass than 10^6 kg is very probable. The body has certainly not been so large as the Sky and Telescope article advocated.

Recently I applied newly invented procedures for meteoroid ablation and fragmentation (Ceplecha & Borovička 1992; Ceplecha et al. 1993) to this fireball and repeated the determination of its initial mass. The deceleration at the perigee point resulted in -0.015 km/s^2. The mass of 4×10^4 kg for stony density,

---

Send offprint requests to: Z. Ceplecha

1994A&A...283..287C

Table 1. Atmospheric trajectory

point		GMT [s]	v [km/s]	h [km]	φ	λ E. Gr.
1	initial	73708.9	15.03	75.98	39.289°	247.425°
2	perigee	73747.5	14.60	57.85	44.386°	247.007°
3	final	73810.1	14.21	101.55	52.331°	246.242°

GMT	seconds of time elapsed from 0^h UT of Aug 10, 1972
v	velocity according to a fixed Earth surface (φ,λ system)
h	height with respect to the surface of the 1971 geoid
φ	geographic latitude
λ	geographic longitude East of Greenwich

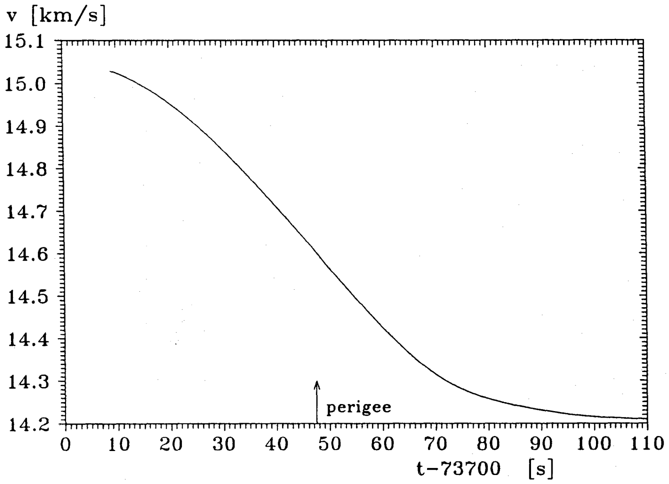

Fig. 1. Velocity as function of time

of 1.4×10^5 for carbonaceous density and of 5.7×10^5 for cometary material of density 0.75 g/cm^3 was computed. The ablation coefficient cannot be well determined with such small values of decelerations. But the initial mass should not be more than twice or three times the mass at perigee. The most probable type of this fireball is II (carbonaceous), which gives 5 m as the dimension of the body at perigee. In case of type I (ordinary chondrite), the dimension would be 3 m; in case of type IIIA (cometary material), it would be 14 m. The remaining mass after the body left the atmosphere is about twice or three times less than that at the perigee. Thus 10 m size seems to be the maximum possibility for the body in its orbit at present. Dark fusion crust due to the partial ablation in analogy to meteorites may add another difficulty in eventual attempt to locate the body optically during the next close approach to the Earth.

3. Orbits

The resulting no-atmosphere ("initial" and "terminal") velocities were

$$v_{\infty B} = 15.083 \pm 0.019 \text{ km/s}$$
$$v_{\infty E} = 14.208 \pm 0.005 \text{ km/s}$$

The classical approach of computing meteor orbits was applied with these velocities and positions from Table 1. The resulting orbits before and after the 1972 encounter are given in Table 2. The body will come again close to the Earth inside the interval from 1997 July 30 to Aug 16 with Aug 8 being the most probable date. The Earth will be at the same point 1997 Aug 11. This is just a rough estimate based on the computed semimajor axis and its standard deviation. A solution incorporating gravitational perturbations during all the 14 revolutions of the body is desirable for any recovery efforts.

Table 2. Orbits (1950.0)

		before encounter		after encounter	
v_G	km/s	10.15	±.03	8.804	±.008
α_G		159.00°	±.02	155.538°	±.007
δ_G		−67.48°	±.08	−19.05°	±.03
v_H	km/s	34.88	±.02	33.878	±.006
ε_G		114.696°	±.016	113.445°	±.009
ε_H		164.67°	±.03	166.206°	±.010
a	A. U.	1.661	±.004	1.4715	±.0009
e		0.3904	±.0016	0.3633	±.0004
q	A. U.	1.0127	±.0000	0.9369	±.0000
Q	A. U.	2.310	±.009	2.0061	±.0019
ω		355.57°	±.08	315.76°	±.02
Ω		317.956°		317.949°	
i		15.22°	±.03	6.928°	±.012

v_G	geocentric velocity
α_G,δ_G	right ascension and declination of the geocentric radiant
v_H	heliocentric velocity
ε_G,ε_H	elongation of the geocentric and heliocentric radiant from the Earth's apex
Q	aphelion distance
ω	argument of perihelion

4. Recommendation

My original paper (1979) corrects the erroneous values published in Nature (1974) and Sky and Telescope (1974) and should be used as a valid reference to original data on this fireball. In the same paper you can also find all the details not mentioned here, more numerical data, explanations of the methods applied, and also original equations of motion with atmospheric ablation in a near horizontal trajectory.

References

Bartky C.D., 1978, Smooth plot of velocity (private communication)

Ceplecha Z., 1979, Bull. Astron. Inst. Czechosl. 30, 349

Ceplecha Z., Borovička J., 1992, Meteors. In Interrelations between Physics and Dynamics of Minor Bodies in the Solar System, eds. D. Benest, C. Froeschle, Editions Frontieres, Goutelas 1991, Gif-sur-Yvette, France, p. 309

Ceplecha Z., Spurný P., Borovička J., Keclíková J., 1993, Atmospheric fragmentation of meteoroids, Astron. Astrophys. (in press)

Jacchia L.G., 1974, Sky and Telescope 48, 4

Rawcliffe R.D., Bartky C.D., Li F., Gordon E., Carta D., 1974, Nature 247, 449

This article was processed by the author using Springer-Verlag LaTeX A&A style file version 3.