The Fall of the Peekskill Meteorite: Video Observations, Atmospheric Path, Fragmentation Record and Orbit.

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Abstract

A general overview of the events surrounding the fall of the Peekskill meteorite is presented.

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1. Introduction:

The events surrounding the fall of the Peekskill meteorite on October 9th, 1992 are quite remarkable. Not only did the meteorite announce its arrival by hitting a parked car in suburban Peekskill, N.Y., but the fireball that preceded the fall of the meteorite was videographed by at least 16 independent videographers.

Eye-witness accounts indicate that the fireball associated with the Peekskill meteorite first appeared over West Virginia at 23:48 UT (±1 min.). The fireball, which traveled in an approximately northeasterly direction, had a pronounced greenish colour, and attained an estimated peak visual magnitude of -13 (comparable to the Full Moon). During a luminous flight time that exceeded 40 seconds the fireball covered a ground path of some 700 to 800 km (Brown *et al.*, 1994). The fireball's ground path and the meteorite recovery location are shown in figure 1.

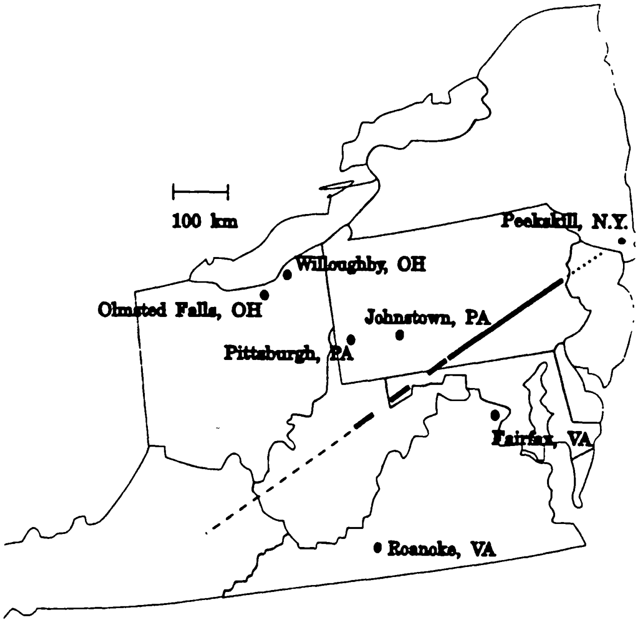

Figure 1. Ground path of the fireball, and the meteorite recovery site at Peekskill, New York. The ground track as actually recorded on video is represented by the solid line; the dotted line represents the undocumented trajectory past the last recorded video image; the thick dashed line is based upon eye-witness observations, while the thin dashed line represents the theoretical initial portion of the trajectory.

The meteorite recovered at Peekskill, New York (41° 17' N, 81° 55' W) had a mass of 12.4 kg, and was subsequently identified as an H6 monomict breccia meteorite (Wlotzka, 1994). The video record suggests (see section 2) that the Peekskill meteorite probably has several companions, however, given the fireball's shallow angle of trajectory (see section 4) the fall ellipse is large (Hughes, 1994). This fact coupled with the harsh terrain that exists in the Peekskill area would suggest that the recovery of related fragments is unlikely.

2. Atmospheric flight - gross characteristics:

To date the authors have collected a total of 16 videographic tapes showing the fireballs passage through the Earth's atmosphere. It is our belief that more videos of the event do exist, and we continue our efforts to search these out.

An analysis of the fireball's atmospheric flight has been made from four of the sixteen videos collected (Brown *et al.*, 1994). The video stations are shown in figure 1, and are located at: Fairfax, Virginia; Johnstown, Pennsylvania; Pittsburgh, Pennsylvania; and Willoughby, Ohio. At the beginning of the video record the meteoroid's velocity and height were 14.7 km/s and 46.4 km respectively.

At a height of ~41.5 km extensive fragmentation of the main meteoroid body took place. Differential induced aerodynamicaly drag subsequently caused a significant, greater than 20 km, longitudinal displacement of the fragments. A transverse displacement amounting to ~1 km also developed in some of the smaller fragments (see figure 2). This latter displacement is presumably the result of either the interaction of individual bow shock waves, or to the fragments receiving an appreciable transverse velocity component at the time of their separation from a rotating parent body. KM has studied the deceleration of several distinctive fragments and finds characteristic dynamic masses of 100-300 kg. Furthermore, a dynamic mass of order 20-25 metric tons is inferred for the parent meteoroid. Radioisotope studies of the Peekskill meteorite (Graf et al., 1994) suggest that the parent meteoroid had an initial radius somewhere between 50 and

Figure 2. Enlargement of a still photograph (by S. Eichmiller) taken from Altoona, PA., showing the many fragments that resulted from the break-up of the Peekskill meteorite's parent body. Note the large transverse displacement shown by many of the fragments.

100 cm. Spherical objects of this size would have masses between ~2 and 15 metric tons respectively. Work is in progress to better define the dynamical and photometric mass of the original meteoroid.

Prior to the main fragmentation event the video observations indicate a significant wake behind the main body of the fireball. A distinctive 'flickering' is also apparent in the wake, and periodic disconnection events take place with an average frequency of 6 Hz. The disconnection events may be due to the rotation of the parent body, or they may reflect an hydrodynamic instability at the wake - ambient boundary. Marc Thuillard (private communication) has suggested to us that the wake flickering may be analogous to the flame flickering observed in isothermal, non-reactive flows. Our analysis of this most interesting phenomenon continues at the present time.

In addition to the wake flickering phenomena, and the fragmentation event, the video record also shows two time resolved flares. The most pronounced flare occurred at a height of ~36.4 km and lasted for just under 1/3rd of a second. RH has investigated the grain sizes that might produce the required lag (~3 km behind the main leading body) and flare duration. The characteristics of the flare are reasonably well explained by the simultaneous ejection of about 1000 grains each of mass ~1 g.

3. Atmospheric flight - electrophonic sounds:

It is now a well established fact that bright fireballs can produce long-enduring electrophonic sounds (Keay, 1993, 1992, 1980). While we were not primarily concerned with collecting eye-witness accounts of the fireball that preceded the Peekskill fall, we did receive many unsolicited reports, and some of these noted the presence of (electrophonic) 'sounds'.

The most detailed account that we have received is that of Patsy Keith and family who were inside a car near Altoona, Pennsylvania when they 'heard' the fireball. The 'sound' was described as a "crackling sound like that of a sparkler." The 'crackling' sound lasted for about 10 seconds, and was audible for several seconds after the first major fragmentation event.

Keay (1993, 1992, 1980), and Keay and Ceplecha (1994) have argued that ELF/VLF radiation will be generated whenever a fireball enters a regime in which turbulent, rather than free-molecular flow is possible. This low frequency radiation, it is argued, may subsequently be 'heard' given the presence of a suitable near-by transducer (Keay, 1993, see also Beech, Brown and Jones, these proceedings). An expression for the transition height at which the flow becomes turbulent has been derived by Revelle (1979).

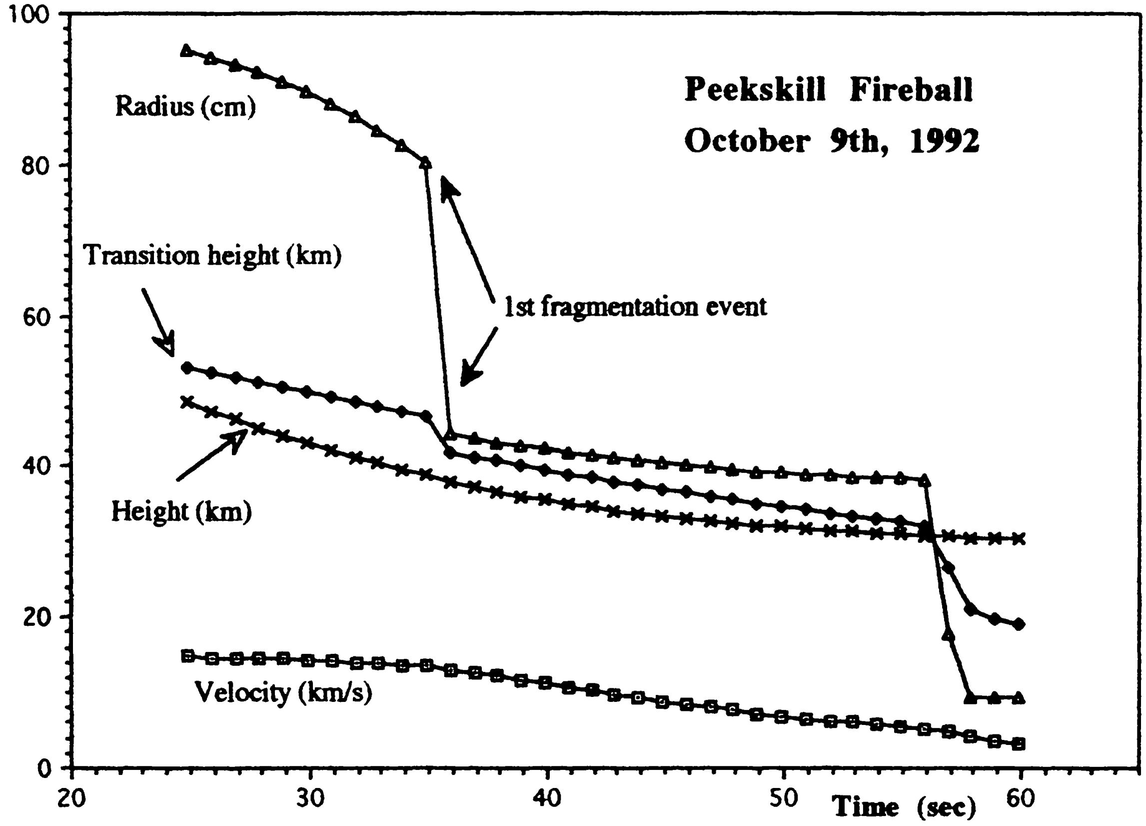

Figure 3. Time variation of the meteoroid radius, height and velocity as determined by single body ablation plus gross fragmentation calculations. Also shown is the transition height for the onset of turbulent flow (Revelle, 1979). The generation of ELF/VLF radiation is predicted to occur once the fireball height is less than that of the transition height (Keay, 1992). The calculations cover those portions of the fireball's flight that were recorded on videotape.

A representative (that is, not a minimum residual analysis) single body ablation plus gross fragmentation model for the Peekskill fireball has been calculated by ZC (see Ceplecha, 1993 for details of the method). The time variation of the model parameters are shown in figure 3. The transition height for the commencement of turbulent flow is also shown in the figure. The model suggests that the fireball was below the transition height for the onset of turbulent flow for most of its luminous flight. The model is consistent with the observations in the sense that long duration electrophonic sounds should have been heard, and that the first fragmentation event need not have resulted in the cessation of electrophonic sound (c/o Patsy Keith's account).

a	(semimajor axis)	1.49 ± 0.03 AU
e	(eccentricity)	0.41 ± 0.01
q	(perihelion distance)	0.886 ± 0.004 AU
ω	(argument of perihelion)	308° ± 1°
Ω	(longitude of ascending node)	17.030° ± 0.001°
i	(inclination)	4.9° ± 0.2°
T	(orbital period)	1.82 ± 0.05 yr
ΔT	(time since perihelion)	41 ± 1 d
Q	(aphelion distance)	2.10 ± 0.05 AU

Table 1. Orbital parameters for the Peekskill meteorite. The errors quoted for each term are ± 2 times 1 standard deviation. The factor of 2 is introduced to allow for the possibility of uncorrected systematic errors.

4. Orbit of parent body:

The Peekskill meteorite is the fourth meteorite in history for which there is a known orbit. The orbital parameters of the Peekskill meteorite are given in table 1. Figure 4 shows a comparison between the orbits of the Peekskill meteorite and those of Innisfree, Pribram and Lost City. The parent body

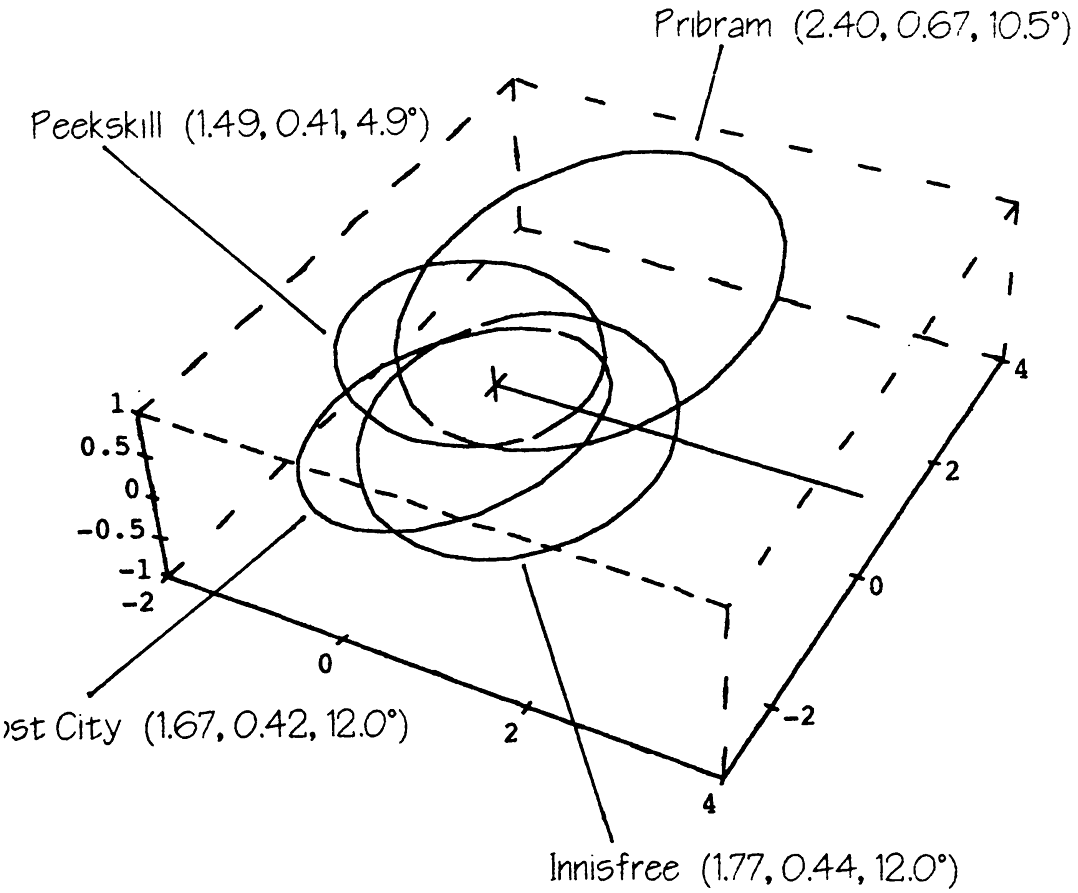

Figure 4. The orbit of the Peekskill meteorite. Also shown are the orbits of the Lost City, Pribram and Innisfree meteorites. The x-axis (long thin line from centre) is in the direction of the Vernal Equinox, and the axis scales are in AU. The small break in each orbit indicates the position of perihelion. The numbers in brackets represent the orbital values of (a, e, i).

of the Peekskill meteorite had an aphelion distance of 2.1 AU, which indicates that it was periodically placed at the inner edge of the main asteroid belt.

The parent body of the Peekskill meteorite encountered the Earth 41±1 days after its last perihelion passage. The Earth - meteoroid encounter geometry was such that had the meteoroid been ~40 km higher at perigee it would have skimmed through the Earth's atmosphere and returned to space.

5. Final Remarks:

The video observations of the fireball which preceded the fall of the Peekskill meteorite have provided a great wealth of hitherto unavailable data. The high time-resolution, and multi-station aspect of the collected video data has enabled us to study in unprecedented detail the passage of a large meteoroid through the Earth's atmosphere. Our study of this most interesting event continues.

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