A very public fireball

Journal Item

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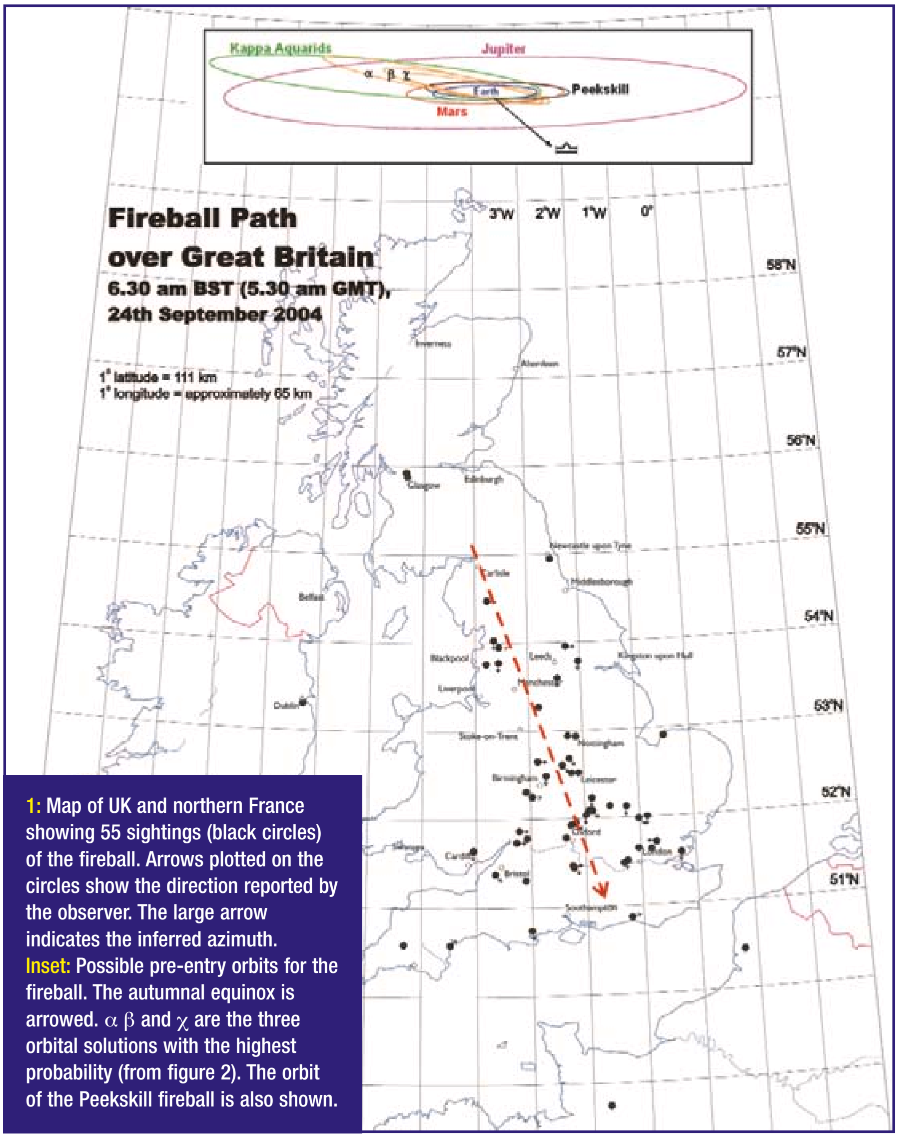
J C Bridges, J P Schwanethal, V K Pearson, M D Paton, R C Greenwood, J S Watson and **G H Morgan** report on a determination of orbital elements of a fireball seen over Britain and Northern France.

Abstract

An appeal for witnesses to a fireball on 24 September produced an excellent response from the public; 55 eyewitnesses sent accounts. From their observations we calculated the radiant azimuth as 320°, and altitude angle ≤20°. Without video or CCTV footage for control on the fireball's velocity or pre-entry orbit, we used software developed for dust impact experiments, to assess the most likely orbital trajectory. The highest probability solutions have a semimajor axis between 1.6 and 2.0 AU and an eccentricity of 0.4 to 0.5, corresponding to a typical near-Earth asteroid orbit. Of possible comet showers, the κ Aquarids are within the calculated constraints. No fragments were found, despite considerable public interest, consistent with the absence of reports of a dust trail. Public response to this fireball demonstrates the great interest in meteoritic phenomena, particularly when, as in this case, participation in the scientific enquiry is actively encouraged.



1: Map of UK and northern France showing 55 sightings (black circles) of the fireball. Arrows plotted on the circles show the direction reported by the observer. The large arrow indicates the inferred azimuth. Inset: Possible pre-entry orbits for the fireball. The autumnal equinox is arrowed. α β and χ are the three orbital solutions with the highest probability (from figure 2). The orbit of the Peekskill fireball is also shown.

On 24 September 2004 a former member of staff at the Planetary and Space Sciences Research Institute (PSSRI) of the Open University in Milton Keynes reported a bright fireball at dawn. Our curiosity kindled, we sought more information via local radio stations and our website. With previous fireballs in mind – Peekskill (eastern USA, 1992) and Park Forest (Chicago, 2003) – we hoped to find associated meteorite fragments and determine an orbit. By the end of the day we had more than 55 eyewitness reports, from Glasgow to Normandy, indicating at least one fireball travelling from north-north-west to south-south-east within a few minutes of 6.30 a.m. (BST).

Observations

Observers mostly described a bright white or blue-white fireball, although two said bright green, and some mentioned the typical "ball and tail" appearance. The visual magnitude maximum was about –13, the same as a full Moon. No loud detonations or dust trails were reported. Witnesses often mentioned flat trajectories and, from their estimates, we put the fireball's path at azimuth 320° and altitude angle ≤20°. The duration and length of its passage is less clear: typical reports were 3–5 seconds. The fireball was visible over 800 km; we estimate that it was at least 250 km long. No northern or French eyewitnesses mention an airburst, but many from the Midlands and south of England reported "bursting like fireworks", "sparks", "shattering" and "explosions".

The number of fireballs remains uncertain. One report described two. We also received some reports of earlier fireballs, including one in Fife at 5.30 a.m. The latter was a clear, double-checked description of a bright green fireball. Figure 1 shows only the 6.30 a.m. fireball.

The green colour of the fireball reported near its NNW end is consistent with the early stages of other fireballs, notably Peekskill (Brown *et al.* 1994). Peekskill travelled over 700 km and lasted for about 40 seconds, bigger and longer than this one. The Peekskill fireball had a starting altitude of 46 km. The September fireball's height is uncertain, but a high altitude like Peekskill is consistent with its wide visibility.

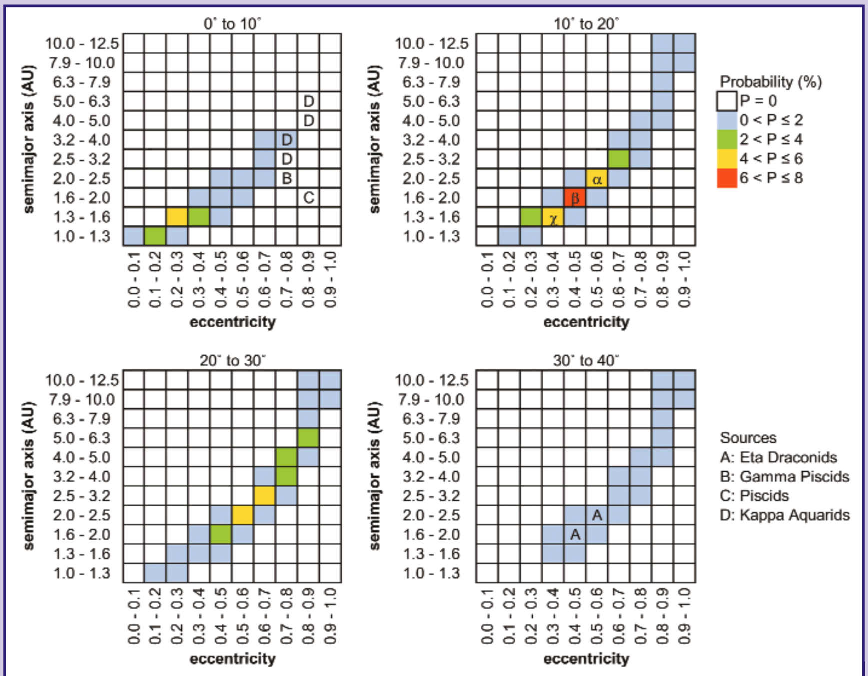
An unusual feature of the 24 September bolide is its timing: fireballs at dawn are usually associated with retrograde comets rather than prograde asteroidal material, which tend to fall from midday to evening. This was clearly prograde and asteroidal fireballs at dawn are known e.g. Tagish Lake (Brown *et al.* 2000).

Disappointingly, no meteorite falls were recorded near the fireball. Both the Bovedy (N. Ireland, 1969) and Barwell (Leicestershire, 1965) meteorite falls were recovered shortly

Pinning down the orbit

Our orbital solutions were determined with ORBELEM (ORBital ELEMents) software, developed at the OU to derive the sources of impacts on dust detectors (Schwanethal *et al.* 2002). For dust, the impact time, pointing history, shape and geometry of the detector constrain the possible incoming direction of a particle. The detector may also indicate the impact speed. The software steps through possible impact trajectories for a range of speeds, defining the range of possible impact velocity vectors.

We used the software to limit possible orbits of the fireball from trajectory information. We assumed that the detector was 40 km above the surface of the Earth. The nominal fireball trajectory was derived from the eye witness accounts, although we assumed a ±20 degree uncertainty in this trajectory. We allowed a full range of fireball speeds since this was not determined from the eye witnesses. *J Schwanethal.*



2: Probability distribution of heliocentric orbital elements for the fireball. Coloured cells indicate possible orbits. α, β and χ are solutions plotted on figure 1. A–D are possible cometary showers.

after observation of their associated fireballs. The lack of recovered stones is either because no relatively large fragments existed (consistent with the absence of dust trails), or larger stones fell unseen. More speculatively, the fireball could have been of cometary origin.

Asteroid or comet? Orbital solutions

In order to fully characterize the pre-entry orbit of a fireball it is necessary to know its velocity. For other events this has been found from video coverage (Peekskill; Brown *et al.* 1994), Fireball Tracking Network cameras (e.g. Innisfree, Canada, 1977; Halliday *et al.* 1981), satellite data (Tagish Lake, Canada, 2000; Brown *et al.* 2000) or, where a strewn field of associated meteorites was found (Mbale, E. Africa, 1992; Jenniskens *et al.* 1994). The PSSRI put out further requests to radio stations and newspapers to try to find CCTV or video footage – but to no avail. The European Fireball Network cameras (e.g. Spurny *et al.* 2003) are too far to the east to have photographed this fireball. No other data – seismic or satellite registrations – expected for the largest fireballs were recorded in Europe or the USA (Spurny, pers. comm.). Therefore we could not positively find the orbit.

However, by using the azimuth and altitude angle from our eyewitness reports we did limit it to a range of orbital elements. Details of the procedure and software used are given in the box "Pinning down the orbit". Figure 2 shows all possible *a-e-i* combinations by coloured cells. A white cell denotes an orbit that cannot be the source of the fireball. The plots show that, without good constraints on either the speed or the trajectory of the fireball, many orbital solutions are possible. Using the inclination of the orbit between 0° and 40°, the semimajor axis and eccentricity both show many possibilities, allowing typical near-Earth asteroid (NEA) type orbits, as well as prograde short period (and Jupiter-family) cometary orbits. However, individual orbital solutions are equally weighted, so the most likely orbit can reasonably be found from the most populated cell. This is seen in figure 2 as a red cell (β), having an inclination between 10° and 20°, a semimajor axis between 1.6 and 2.0 AU and an eccentricity of 0.4 to 0.5. This is a typical NEA orbit (Kowal 1996), and suggests that the body giving rise to the fireball was most likely to be an asteroid. That said, higher eccentricity cometary orbits cannot be ruled out from figure 2. Only the η Draconids and κ Aquarids are possible. However, the η Draconids shower is very weak and so is an unlikely candidate. The κ Aquarids are among the top 50 most prominent annual showers (Jenniskens 1994) and their peak occurs within a week of the fireball. The shower's apparent activity is relatively low, but meteor brightness is a strong function of velocity. The κ Aquarids are a very low velocity shower, implying that the shower is actually relatively important in terms of a flux of large particles (see McBride, 1997). Thus, although the NEA origin appears to be the most likely, a body from this meteor shower cannot be ruled out.

We were pleased by the great public interest and the quality of eyewitness responses. As a result, we were able to estimate possible orbits for the original bolide, despite the lack of velocity or altitude information. In the future we hope to publicize such events as widely as possible, in order to deduce the orbital tracks associated with fireballs, and possibly to locate debris. In the UK, with its uneven topography, wet climate and often dense vegetation, meteorite finds are virtually unheard of. Alerting the public to possible meteorite falls that could be associated with fireballs, dust trails and detonations, could change that. ●

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Jen Stewart made the initial sighting. Colin Pillinger and many members of the PSSRI contributed to the gathering of the eyewitness reports and discussion. Dan Andrews helped with the orbital solutions. We thank everyone who gave eyewitness reports to the PSSRI together with the radio stations and newspapers that sent out requests for eyewitnesses.

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