A very public fireball

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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 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 after the events, suggesting that the fireball did not disintegrate in the atmosphere. However, the high visibility of the fireball and the interest generated by the public suggest that there may be potential for future discoveries of meteorite fragments or other debris from this event.
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.

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 strew 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 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 k 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.

References

Association of Lunar and Planetary Observers www.bl.arizona.edu/ALPO.

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.

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Jon Stewart made the initial sighting. Colm 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.