THE WINCHCOMBE CARBONACEOUS FIREBALL – THAT LUCKY SURVIVOR

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Introduction: In February 2021, Winchcombe became the first meteorite recovered in the UK in 30 years. Classified as a CM2 chondrite, it was recovered only hours after fall, largely limiting terrestrial contamination [1]. The fireball was also very well instrumentally recorded, providing good insights on the meteoroid's structure and its orbital history.

Main results ([2]): The Winchcombe meteoroid was only 13 kg before entry at 13.9 km/s on a 42° slope, and only encountered ~0.6 MPa peak dynamic pressure. Orbital integrations show that the meteoroid was injected into the near-Earth region recently (50% of particles between 0.035 and 0.24 Myr), and that it never had a perihelion distance smaller than ~0.7 AU. ~0.6 kg of rocks were found, in agreement with dynamics and fragmentation modeling.

Conclusions:

Carbonaceous material survival bias

Before Winchcombe, all instrumentally observed carbonaceous falls were all multi-ton initial objects, and were mostly destroyed upon impact. [3] showed that their survival was due to the presence of some stronger lithologies in the rock.

Winchcombe was different, it was a small initial body, and it avoided >1 MPa dynamic pressures during entry. This was thanks to its relatively low speed and entry angle, a narrow range of conditions that allowed to decelerate enough before hitting the thicker layers of our atmosphere.

This allowed material that would otherwise had got destroyed to survive entry. Winchcombe proves that carbonaceous decimetre-sized meteoroid can also drop meteorite, although the bias against these objects surviving is strong.

Delivery timeline to Near-Earth space

The exposure age of a meteorite indicates how long the sample has been part of a very small body, or been close to the surface of a larger body. Most meteorites have exposure ages >10^6 yr, longer than their NEO lifetimes. This points to distinct steps for delivery to Earth: collision in the asteroid belt, Yarkovsky drift into an orbital resonance, orbit change due to the resonance until inner planet crossing, and then mostly gravitational evolution in Near-Earth space, followed by impact on Earth [4]. CM chondrites (including Winchcombe), in contrast, have relatively short exposure ages (~10^5 yr). With Winchcombe we established that the events: "separates from a present day parent body" and "enters Near-Earth space" are contemporary. Because of uncertainties we cannot tell which happened first, but we know that both were recent, in the last 0.3 Myr, questioning what the ejection mechanism and timeline were.

State vector change

The location of the meteorites found form a 600 m wide corridor, significantly more than the uncertainty on the nominal trajectory. A significant direction change of at least 90 m/s is observed from a single viewpoint right at the end of the bright flight on the main fragment. The physical phenomenon could not be definitely determined, but it is a critical factor in shaping strewn fields [5]. A consequence is that without detailed observations at both high-resolution (arcminute) and high sensitivity (mag 0) of the very end of the bright flight, it may not be possible to predict meteorite fall positions to better than a few hundred metres.

Data sharing

The analysis of the Winchcombe fireball involved 5 independent meteor observation networks in the UK. Although the networks were set up independently, with different software routines for capturing and processing data, it was possible to combine the astrometric data from all rapidly thanks to the proposed standard of [6]. This enables a quick turnaround time from the time the fireball happens to when a fall area is calculated.

References:

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