A Preliminary Report on the Chelyabinsk Fireball/Airburst

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At 03^h20^m UT (09^h20^m local time) on 2013 February 15, a bright, long-lasting fireball was widely observed over the region of Chelyabinsk, Russia. Eyewitness reports extend out to more than 700 km. This event was of such large energy that the shock wave reaching the surface had sufficient overpressure to blow out windows, doors and cause light structural damage particularly in the region to the South of Chelyabinsk, as well as in the city of Chelyabinsk. According to Russian media reports, over 1000 people were injured by flying debris (mainly broken windows) as a result of the shock wave. Many small meteorites, apparently ordinary chondrites, and by some reports L-type chondrites, have been recovered.

As this report is written one week after the event, some general features of this airburst are reasonably well established. From video recordings (Borovicka et al., 2013) and US government sensor data, the initial entry velocity of the fireball was about 18 km/s at a shallow angle of 16 degrees from the horizontal. The orbit of the object prior to impact was a typical Apollo-type with low inclination. The energy of the event has been estimated from the dominant airwave period at Infrasound frequencies to be approximately 500 kT of TNT equivalent. The airwave from the airburst was recorded by infrasound sensors over the entire globe; some records show at least one full revolution of the planet (including antipodal returns) some 24 hours after the event. This is the furthest any fireball airwave has been detected infrasonically since Tunguska.

Among these values, the greatest uncertainty is in the energy estimate – it could easily be a factor of two different from above. However, based on the airburst altitude (established by Borovicka et al. (2013) as 25–30 km) and the overpressures observed at the ground, yields below 100 kT can almost certainly be ruled out; the event was most likely in the several hundred kT energy range.

The range of energy yields translates into a meteoroid with a mass of order 10^4 tonnes and diameter of approximately 20 m. Many hundreds of video recordings of the event, including at least 30 direct videos showing the fireball, were obtained and posted to social media sites. Some videos show the distinct formation of strong local vertical plumes associated with intensive heating in the terminal detonation. The main airburst section of the trail shows a distinct double trail formation (as was also seen with the Tagish Lake fireball), likely indicating fast rising air flowing into the center of the trail – essentially a moving 3D version of a mushroom cloud. Based on video recordings, extrapolations of empirical mass-yield-brightness estimates from other bright fireballs and appealing to entry models of airbursts in this energy range, I estimate the peak absolute magnitude reached by the fireball to be in the -27 or -28 range; directly under the terminal detonation the apparent magnitude may well have exceed -30.

This fireball event is the most energetic confirmed airburst since the Tunguska fireball of 1908. Assuming the 500 kT yield is correct, the Earth is hit, on average, by a similarly energetic object only once every ~ 75 years.

By coincidence, the asteroid $2012\,DA_{14}$ made a close pass to Earth (less than 30 000 km from the surface) just 16 hours later. The two objects have very different orbits and an association is very unlikely.

This extraordinary event marks a turning point in the study of objects colliding with the Earth, particularly the public perception of such events. I expect it will be recorded as a watershed moment for meteor science, marking the point when growth and interest in the field dramatically increased.

References

Borovicka J., Spurny P., and Shrbeny L. (2013). "Trajectory and orbit of the Chelyabinsk superbolide". *CBET*, **3423**.

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