# 2015 Easter bolide over North Hungary

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On Easter Monday, April 6, 2015, at UTC $17^h31^m$ (near sunset) there was a bright (peak magnitude -12 ~ -14) bolide which also produced a sonic boom, over North Hungary, close to Miskolc, above the Bükk mountains. The event was witnessed by many people, and recorded by several car dashboard-, meteorological and all sky cameras from as far away as Farád (North-West Hungary) and Görbeháza (North-East Hungary). Unfortunately, with the event having occurred only a few minutes after sunset, the sky was still bright and therefore the Hungarian Video meteor network cameras were not yet operating. Our team has collected and re-calibrated as much video and photo material as possible. Since there were very few direct images of the bolide itself, but more photos and videos of the persistent train left behind, these latter images were also used, in certain circumstances, in our calculations. The deduced final atmospheric path and heliocentric orbit are presented, along with the estimation of the errors.

## 1 Introduction

Reports of a bright bolide over Miskolc near sunset on 2015 April 6 (the second day of Easter Holidays) were received via Facebook messages and Web blog alerts to the Hungarian fireball Website and blog[1] (the founder and operator of which is one of our authors, Zs. Bíró. Soon afterwards, several private webcam, car dashboard camera and mobile phone images were also uploaded (see *Figures 1–3* for the best images), along with many accounts written by witnesses. Unfortunately, very few of these eyewitness accounts were informative enough (lacking reliable coordinates for the start and end points of the visible path). However, a persistent train was well seen along the path of this bolide. This had a helical pattern and drifted with the upper atmospheric winds for more than 10 minutes. Since sonic booms had also been reported, seismic records were also obtained from the nearby geophysical stations. Since we believed that a scattered fall of meteorites was a possibility, we attempted to calculate the atmospheric trajectory as well as the Solar System orbit of the original meteoroid body.

*Figure 1* – Fireball seen from Farád (North-West Hungary).

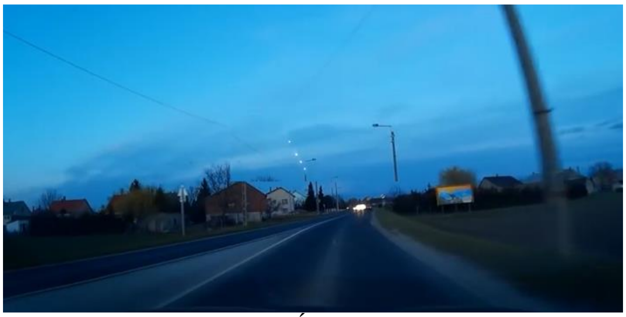

*Figure 2* – Fireball seen from Újpest (Hungary).

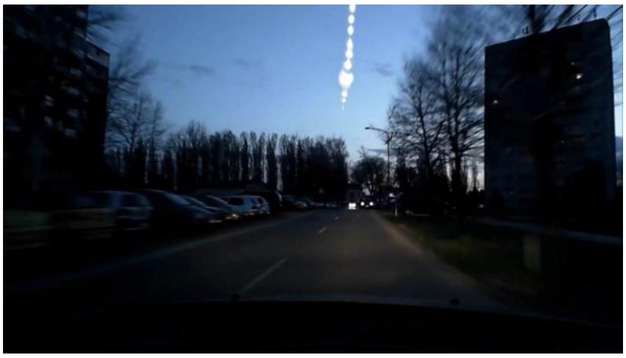

*Figure 3* – Fireball seen from Kasa (North-West Hungary).

## 2 Calibration of input

Unfortunately, the bolide appeared immediately after the sunset, when none of the stations of the Hungarian or nearby countries' video meteor camera networks were in operation. Since most of the uploaded images were poorly documented, the geographical positions being

[1] http://tuzgomb.blogspot.hu/

specified incorrectly in some cases and absent in others, – we first carefully reconstructed the geometry of each site (position of the cars at the moment of the exposures) and we corrected for the optical distortions of the camera lenses where necessary. After these preparations, we performed the astrometry of the available images, using a step-by-step improvement for the local horizon. In some images we found Venus, which resulted in a better calibration. The final output from this calibration was a set of Azimuth and elevation coordinates for several, well-identified points along the visual path (e.g. there were two flashes during the flight). As a second approach, we attempted to identify images of the dust trail that had been exposed at nearly the same moment but from different sites. Using some very clear and easily recognised details on the trail, we were able to identify some simultaneous positions on 3 photos, and included these in our parallax computations. The whole calibration method was developed and performed by one of our team (Z. Zelkó). The method is flexible, is not automated, and is not yet fully defined, so it is not yet ready for publication. Some key steps need to be varied from case to case, to allow for specific issues (e.g. optical distortions and other defects) with the available photographic material.

## 3 Atmospheric trajectory and orbit calculation

As usual, we used two computational methods based on slightly different ideas. One was based on the original concept of Ceplecha (1987, programmed by one of our team, Sz. Csizmadia), while the other was based on an original piece of work (published in Hungarian language only, T. Hegedüs, 1986). As in many previous cases, both methods were used in parallel, and the results were compared and discussed thoroughly during the analysis.

The results presented below were produced by using all possible double station combinations of the cameras that recorded the visual path simultaneously (Farád, Újpest in Hungary and Kosice in Slovakia) and, separately, by then using, all double station combinations of the sites where the persistent train was recorded (Bekecs, Csobád, Görbeháza). The averages and the estimated errors for all resulting geometric parameters for both runs are shown in *Table 1*. The visualisation of this path on GoogleMap can be seen in *Figure 4*. As a control, we combined all three sites into one calculation, for both cases as above. Images had also been available from a few other sources with lower quality (in some aspects). Due to the uncertainties arising during their calibration, these were not included in these calculations (e.g. Baskó, Piszkéstető, Rakamaz, Sárospatak).

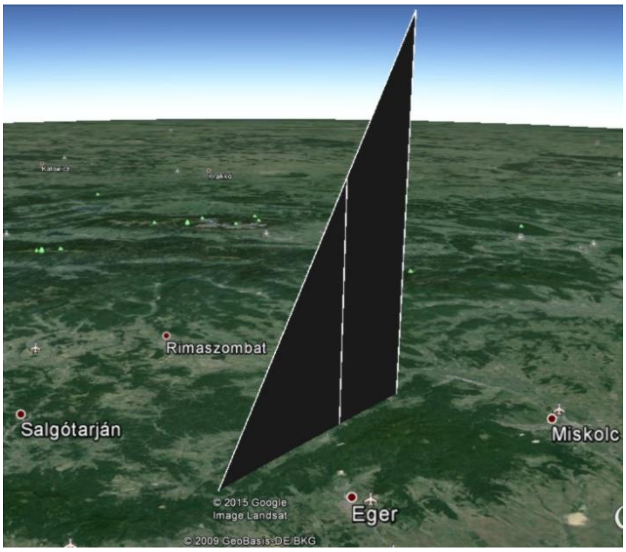


*Figure 4* – Reconstruction of the Fireball trajectory.

The average geocentric speed was found to be 18.5 ± 2.3 km/s when calculated from the visual path, and 13.2 ± 0.1 km/s when determined from the dust trail. Estimates for the original mass were between 500 ± 200 and 1600 ± 800 kg (again for the visible path and dust trail determinations, respectively) using an accepted -12 $^{mg}$ peak luminosity.

*Table 1* – Geometry of the atmospheric trajectory of the bolide, determined from all possible double simultaneous image recordings.

| | | Start | | | End | | | Linear intersection | | Radiant (2000.0) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Latitude (°) | Longitude (°) | Height (km) | Latitude (°) | Longitude (°) | Height (km) | Latitude (°) | Longitude (°) | α (°) | δ(°) |
| Double station visual path | **average:** | **48.1970** | **20.5020** | **53.9** | **48.0990** | **20.3794** | **33.9** | **47.9314** | **20.1720** | **177.12** | **64.734** |
| | Error: | ±0.037 | ±0.130 | ±3.9 | ±0.027 | ±0.094 | ±2.1 | ±0.020 | ±0.052 | ±8.7 | ±3.16 |
| | Error in km: | ±2.8 | ±14.5 | | ±2.0 | ±10.5 | | ±1.5 | ±5.8 | | |
| Double station. dust trail | **average:** | **48.1932** | **20.4617** | **50.8** | **48.0830** | **20.2991** | **31.2** | **47.8994** | **20.0277** | **188.98** | **60.353** |
| | Error: | ±0.003 | ±0.005 | ±0.4 | ±0.010 | ±0.031 | ±2.4 | ±0.068 | ±0.137 | ±13.5 | ±4.73 |
| | Error in km: | ±0.2 | ±0.6 | | ±0.7 | ±3.4 | | ±5.1 | ±15.2 | | |

The heliocentric orbital elements deduced were:

$a = 2.04 \pm 0.2$ AU,
$i = 14.03^{o} \pm 0.55$,
$e = 0.50 \pm 0.03$,
$\Omega = 15.7^{o} \pm 0.0$,
$\omega = 192.9^{o} \pm 0.6$,
$q = 0.992 \pm 0.001$AU,
$v_h = 36.4 \pm 0.4$ km/s.

The identification of a possible parent body is still under consideration.

## 4 Discussion and remarks

Due to the very inaccurate input sources for this event, the results have very large error bars in the geographical positions of the main points of the path. In addition, we did not have wind speed data and thus we could not perform any estimation of the side-drift of the fallen pieces. In spite of these facts, we decided to organize several mini-expeditions to the probable areas, as deduced from our best calculations. The most extensive searches were led by one of our team (Zs. Kereszty). We carried out a systematic visual search with a metal detector in the fields and also communicated extensively with the local inhabitants. Nothing has yet been found.

As a further interesting fact, according to private communication by Dr. Tímár. G., the seismic stations KECS, LTVH, PENC, AMBH confirmed two booms. The height of the first was estimated to be at about 30 km, above the geographical position N~48.117°, E~20.560° . However it is noted that one closer station (code: PSZ) did not record any booms.

## Acknowledgment

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The author *Tibor Hegedüs* (at right) talking to *Teodor Pinter* (at left) (Photo by *Axel Haas*).