Fireball above lake Balaton, Hungary

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A bright fireball appeared on 2021 October 21, at 16ʰ28ᵐ UT over the Balaton Lake in Hungary. The trajectory, strewn field and orbit could be calculated. The results are presented in this article.

1 Introduction

On the evening of October 20, 2021, at 18ʰ28ᵐ (local time), the lucky ones could see a bright fireball. Due to the early evening time, most meteor camera systems had not yet started. On the other hand, meteorological cameras and many car cameras, have successfully captured the phenomenon (*Figure 1*).

2 Initial data

According to the measurements, the meteor first appearance occurred at 91 km with an entrance angle of 68 degrees at a velocity of 17 km/s, it moved along a 67 km long trajectory through the atmosphere in just 4 seconds. The trajectory was situated between Padragkút to Révfülöp, where it was last seen at an altitude of 24.8 km. I used only the images of the meteorological cameras for the measurement, before the information calculated from the professional systems has been published. I used UFOAnalyser and UFOOrbit (Sonotaco, 2009) for the trajectory calculation.

3 Dynamical mass

By measuring the best recording of the end of the fireball trajectory, I was able to get closer to calculate the remaining mass. This picture was from one of the cameras on the VMETEO site (*Figure 2*), which recorded the end of the fall from close (from Veszprém, from a distance of 40 km). Bence Gucsik saved star background pictures from that camera and asked Mónika Landy-Gyebnár (camera operator) for the exact coordinates of the camera. The camera recorded the last moments of the fall on 7 frames, measuring them frame by frame provides the basis for the current mass and strewn field calculation.

As this camera was the closest to the fall, it could register the end better. The meteor could be tracked far more on the recording, than from another cameras, down to an altitude of 24.8 km. During this time, its speed decreased from 9 km/s to 3.75 km/s. Let’s not forget, that while this is the last light we recorded of the fall, it doesn’t mean the body has switched to dark flight at this point. The picture was taken at a clear sky and this camera is not so sensitive to dim lights. Therefore, the remaining mass probably got a few hundred meters deeper than that. Continuing the rate of deceleration, the assumed final altitude was 24.6 km at 2.5 km/s.

From the speed measured frame by frame, knowing the deceleration and the current altitude, one can calculate how

Figure 1 – Fireball 2021 October 21, at 16ʰ28ᵐ UT, photo made by Schmall Rafael from Kaposfő, Hungary.

Figure 2 – Fireball 2021 October 21, at 16^h28^m UT[26].

much mass is required for this trajectory. (Halliday et al., 1996). Based on this, we obtain as result a 1.2 kg body on the last frame. Once again, this is not the end of the ablation, so it has fallen even further and ablated presumably until less than 1kg. However, based on the recording, this appears to be one body throughout the flight. If it was fragmented into several pieces at the end, this didn't happen at this distance (about 40 km). Continuing the ablation process, the Monte-Carlo modeling dispersed around 880 g.

4 Strewn field calculation

I modeled the dark flight with these data using two different wind profiles at 12^h UT and 00^h UT from Budapest (data came from University of Wyoming, Atmospheric sounding[27]). The remaining mass was given as 100 g – 1 kg. The beginning heights of the bodies varies from 25.1 km to 24.6 km, along the calculated trajectory. The gravitational deflection - the difference between the calculated straight-line path and the real curved trajectory - was not taken into account because it's negligible compared to e.g., wind measurement uncertainties (it was only 27m). My program doesn't handle in-flight fragmentation yet, so it's even possible to find smaller pieces at the 'large fragments' end of the strewn field, but it has to be still in the calculated field. Unfortunately, the results for the 12^h UT and 00^h UT models are very different. Since the fall was between the two, at 16^h28^m (UT), it can be assumed that the fragments that felt are likely to be between the two calculated strewn fields.

For this fireball, many parameters and the observed characteristics support the probability of meteorite fall. So, I posted a little article about it on Facebook. After this, there were some people who dedicated their time to search the area individually but this yielded no findings.

Czech professional astronomers (Spurný et al., 2021) have also calculated data from this fireball, based on images captured by cameras from the European Fireball Network. They have also published their results, from which much can be learned for a citizen scientist like me. Their calculated trajectory came out 800 meters west (yellow) from mine (white) (*Figure 3*), and the final altitude was calculated to be 26 km, instead of the 24.8 what I had calculated. Partly because of this, due to the difference in height, the center line of their calculated strewn field shifted 1.2 km to the SE compared to what I calculated. Based on their published information, I also calculated the strewn field, this can be seen at the edge of the yellow field they calculated. So, it can be seen that the strewn field started from above, gradually shifting into their strewn field result (yellow) (*Figure 4*). However, this alone is not enough to fully match the results. Unfortunately, I don't know what causes the extra difference, because I don't have either their exact starting data or the program, they're using to make their calculations. I use my own program to calculate the strewn field.

What is encouraging, however, is that there are no huge differences. They also gave a few hundred grams to the remaining mass. This proves that using the images and videos of meteorological cameras, a possible meteorite dropping can be approached within 1000 m.

[26] https://vmeteo.hu/
[27] University of Wyoming - http://weather.uwyo.edu/upperair/sounding.html

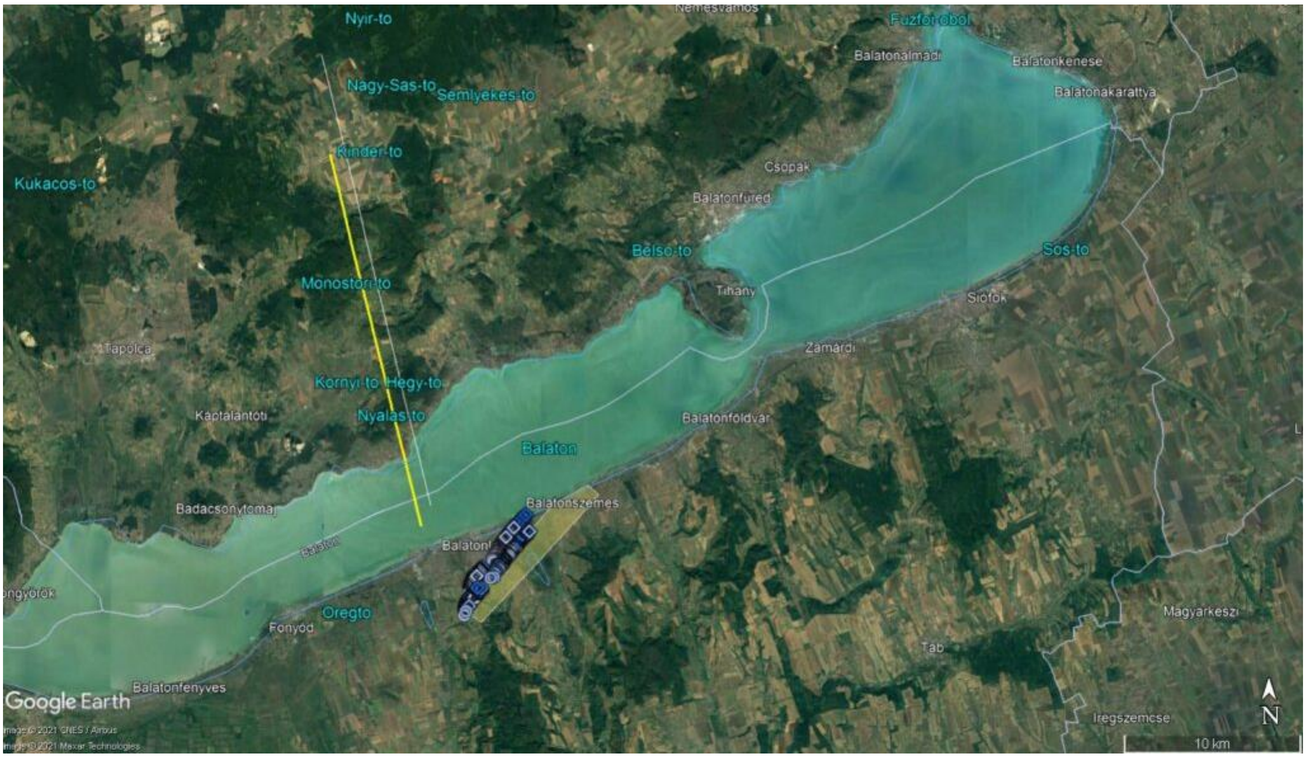

Figure 3 – Fireball 2021 October 21, at 16^h28^m UT, the two different trajectories.

Figure 4 – Fireball 2021 October 21, at 16^h28^m UT, different strewn field calculations.

5 Orbit

Before the collision with the Earth atmosphere this fragment followed a bit an unusual orbit around the Sun. In general, the fireballs come from between Mars and Jupiter, but this one barely reached the orbit of Mars. Therefore, this one was definitely a piece of the innermost part of the main asteroid belt. No known meteor shower could be associated.

The resulting orbital elements are:

- α = 273.9°
- δ = +68.6°
- a = 1.2 A.U.
- q = 0.993 A.U.
- e = 0.186
- ω = 191.2°
- Ω = 207.2°
- i = 24.2°

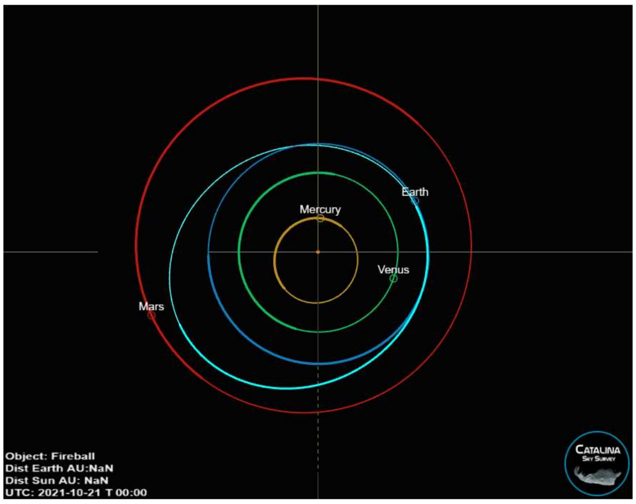

Figure 5 – Calculated orbit in UFOOrbit (Sonotaco, 2009) (Image credit: CSS, D. Rankin).

References

SonotaCo (2009). "A meteor shower catalog based on video observations in 2007-2008". *WGN, Journal of the International Meteor Organization*, **37**, 55–62.

Halliday I., Griffin A.A., Blackwell A.T. (1996). "Detailed data for 259 fireballs from the Canada camera network and inferences concerning the influx of large meteoroids". *Meteoritics & Planetary Science*, **31**, 185–217.

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