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The extraordinary grazing fireball over Central Europe on March 31, 2014

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Abstract

On the evening of March 31, 2014, a grazing fireball (i.e., a meteoroid entering the Earth atmosphere under very shallow angle) was observed by hundreds eye-witnesses in the Benelux countries, France, Switzerland, Southern Germany and Austria. We made detailed images of the fireball with the all-sky cameras of the DLR Fireball Network. In this study we report results of the analysis of this exceptional event and provide preliminary characteristics of the meteoroid.

1. Introduction

The very slow moving and exceptionally long-lived fireball was recorded by a web cam in Ulm/Blaustein over 34 seconds, from 20h 33m 41m until 20h 34m 15m UT. The fireball was also photographed by two analog all-sky cameras of the DLR Fireball Network. With the rotating shutters used in the cameras, a precise determination of the meteoroid's trajectory, velocity was possible. Also, owing to the long duration of the fireball comparably good deceleration data could be obtained, useful for modeling of the meteoroid's physical properties.

2. Data Reduction

According to the reduction of the images of the cameras 87 Gernsbach (Fig. 1) and 85 Tuifstädt, the fireball entered the Earth's atmosphere at an angle of 84° from the vertical and began its luminous path 72.5 km high over the French/German border, between Sarreguemines and Saarbrücken, and was at a height of 39.5 km when it left the field-of-view of the all-sky cameras. Using registrations by further web- and digital cameras, the final point of the instrumentally registered part of the trajectory was determined at 36 km height over Dorfen, Germany.

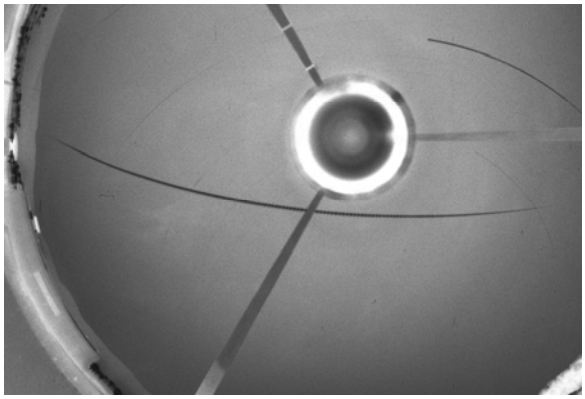

Figure 1: The fireball observed from station Gernsbach.

The slow-moving fireball had an initial velocity of only 13.5 km/s. Unlike other meteorite-producing fireballs with instrumentally registered atmospheric trajectory, the deceleration rate along the trajectory was very low and did not exceed 0,5 km/s^2. The original fit of the entry track resulted in a number of internally timed coordinate points. A deceleration model (implemented in the "fb_entry program", Lyytinen and Gritsevich, 2013) has been applied in

several variations for the both, the standard and actual atmosphere model. Besides using a single whole-trajectory fit, with derived fixed ballistic coefficients and mass-loss parameters, the software was upgraded to account for the explicit velocity and deceleration of the meteor in the terminal part of the trajectory with best temporal resolution..

The resulting dynamic terminal mass has been estimated based on this analysis (Gritsevich, 2008) to be about 20-30 kg. However, according to visual observations of the fireball, the main fragmentation happened well after this. Therefore a series of dark flight simulations was conducted from this fragmentation point reported by eyewitnesses in assumption for different size fragments smaller than our terminal mass estimate. The strewn field from this modeling covers a very elongated area from Germany to Austria aligned with the direction of the fireball track. The larger fragments are expected to land on the Austrian side, but a larger number of fragments, mainly smaller than 100 grams may be found in Germany. Very likely some fragmentation also happened before the main fragmentation event, reported by eyewitnesses, so the resulting total strewn field is expected to be narrow, but very scattered.

3. Orbit

A pre-atmospheric Apollo-type orbit of the meteoroid was obtained based on integration of differential equations of motion (Fig. 2).

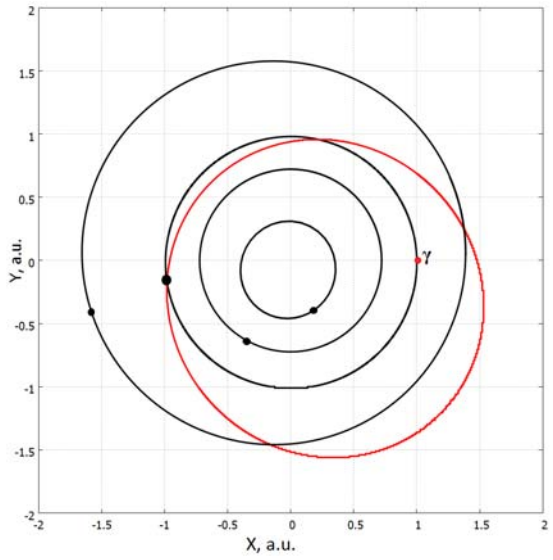

Figure 2: The meteoroid orbit (projected to the ecliptic plane) and its relative position to the orbits of Mercury, Venus, Earth, and Mars.

Table 1: Dynamic data of the meteor and and corresponding orbital elements of the meteoroid

Initial data	
Lat, deg	49.15199
Lon, deg	7.07309
H_b, km	72.483
Slope dist, km	280.452
Az, deg	102.901
Elev, deg	6.973
V, km/s	13.5
Event time, UTC	2014-03-31T20:33:41.0

Orbit	
a, AU	1.264 ± 0.021
e	0.304 ± 0.012
i, deg	4.480 ± 0.075
Ω, deg	190.859 ± 0.003
ω, deg	299.127 ± 1.319
M, deg	31.490 ± 1.510

4. Summary and Conclusions

We estimate the pre-atmospheric mass for the grazing fireball of March 31, 2014 at approximately 200 kg, and expect that numbers of small meteorite fragments were dropped. Based on the dark flight modeling for the fragmented meteoroid, we suggest search campaigns in the calculated impact area.

References

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