THE BUNBURRA ROCKHOLE METEORITE FALL IN SW AUSTRALIA: DETERMINATION OF THE FIREBALL TRAJECTORY, LUMINOSITY AND IMPACT POSITION FROM PHOTOGRAPHIC RECORDS.

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Introduction: Precise fireball data, especially for the cases with recovered meteorites, are very important and provide information about the population of small interplanetary bodies in the Earth's vicinity and also about their parents – asteroids and comets. Backward numerical integration of known orbit provides valuable information about the type of evolutional path of the meteoroid in the solar system, and even can yield the link to the particular parent body. Similarly important is the study of the processes accompanying meteoroid atmospheric flight. The known properties of the meteorite (density, mass, shape, etc.) enable calibration of the fireball data, so that other fireballs without recovered meteorites can provide relevant information on the physical properties of respective meteoroids.

It is extremely rare that any of these meteoroids survives atmospheric flight to be recovered as a meteorite on the ground. Only in 9 cases was the fireball preceding a meteorite fall instrumentally recorded from at least two sites, so that its atmospheric trajectory and orbit could be determined. However, only four of them were recorded by dedicated programs, namely Příbram, Czechoslovakia in 1959 [1], Lost City, USA in 1970 [2], Innisfree, Canada in 1977 [3] and Neuschwanstein, Germany/Austria in 2002 [4]. For all these four cases the meteorites were recovered in the predicted impact locations on the basis of evaluation of available photographic records. The situation for the other 5 cases was reversed, meteorites were found prior to evaluation of the casual records. The precision and reliability of trajectories, velocities and orbits for these cases varies widely, from relatively good, to rather less trustworthy, according to kind, quality and number of available records.

Here we report a new instrumentally recorded meteorite fall, which was recorded by the Desert Fireball Network (DFN), an ambitious project dedicated to mapping of fireballs over the remote area of the Nullarbor Region of SW Australia, a very suitable place for meteorite recoveries [5].

Instruments: To satisfy basic requirements for an instrument able to work in hostile desert conditions, we have modified the Autonomous Fireball Observatory (AFO), a very modern and complex instrument for fireball observations already developed by Spurný and co-workers for the European Fireball Network [6]. The result is a Desert Fireball Observatory (DFO). After two years of successful tests we established a small network consisting of three stations in the Nullarbor Region of SW Australia in December 2005. The fourth station was set up in November 2007. Three years of regular operation have shown that the network performs flawlessly. About 40 fireball orbits were obtained, including 5 probable meteorite falls.

Results: The reported meteorite fall occurred over SW Australia on July 20th, 2007 at $19^h13^m53.2^s \pm 0.1^s$ UT. This time is valid for the photographic beginning of the fireball. The fireball designated DN200707 (Fig.1) was recorded by two eastern stations of the DFN. The geometry was unfortunately far from ideal because all the trajectory was out of the network area, and very close to the horizon at both stations. The distance from the first, closer station varied from 188 km in the beginning to 127 km at the end point; and for the second station from 316 km to 264 km, which corresponds to angular heights above the horizon in the range from only 9.7° to 5.8°. However, thanks to the very precise imaging system (large format fish-eye lens Zeiss Distagon 3.5/30mm), and high resolution of the photographic emulsion, we were able to reduce both all-sky images and get very precise and reliable results on atmospheric trajectory, dynamics, luminosity, orbit and impact position as well.

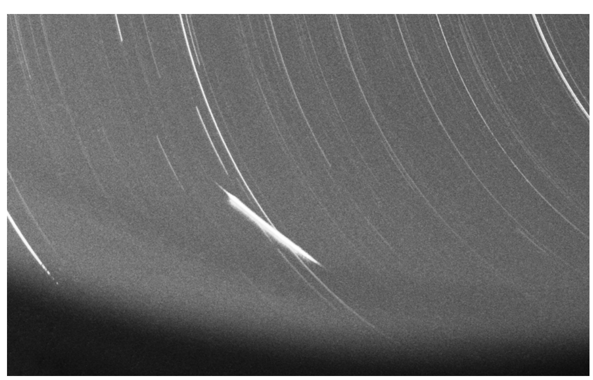

Figure1. Detail of the fireball from station DFO2

The atmospheric trajectory and light curve. The fireball's luminous trajectory started at an altitude of 62.83 km and after 64.7 km long flight terminated at an altitude of 29.59 km. The angle of the atmospheric trajectory to the Earth's surface was 30.9°. The object, with initial mass of about 50 kg, entered the atmosphere with a very low speed of 13.40 km/s, and during 5.7 seconds of flight decelerated to the terminal speed of 5.7 km/s, when the fireball brightness decreased below sensitivity limit of both DFOs. The maximum absolute (100 km distance) brightness of -9.3 magnitude was reached after a very steep increase, surprisingly near the beginning at an altitude of 54.8 km. After a small decrease it stayed almost constant near the end where 3 smaller flares were observed. This behavior is well documented on Figure 2 where the high time resolution (500 samples/s) lightcurve from the DFO02 brightness sensor is shown. This lightcurve represented in intensities is not corrected for distance, and therefore the peak near the end is a little bit higher than the bright part near the beginning. Numerous fast changes in luminosity are another interesting feature on this lightcurve; they are typical for type I fireballs as described in detail in [7].

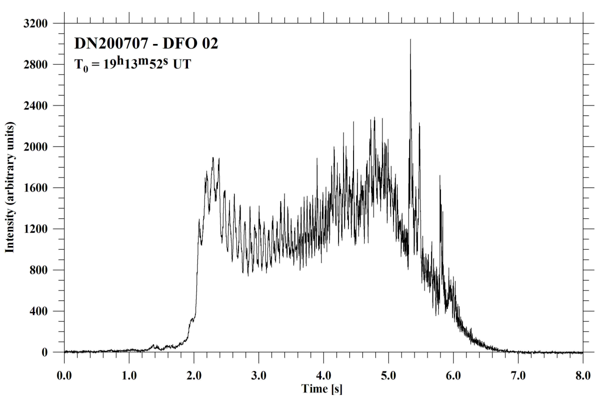

Figure 2. Lightcurve of the DN200707 from DFO02

The darkflight, and meteorites positions. The computation of the darkflight, and determination of impact position, was complicated by the fact that the terminal height was relatively high - almost 30 km (i.e. 6 minutes of the darkflight for 100 g meteorite!) - and terminal mass determined from dynamics was only about 1 kg in the maximum. It was a great challenge because all previous recovered cases were deeply penetrating fireballs with terminal heights below or around 20 km, and with much larger terminal masses. Moreover, our situation was still more complicated by very strong stratospheric wind reaching 50 m/s, shifting the resulting impact position for 100 g meteorites by about 7.6 km! The most probable mass of meteorites from our models was somewhere between 100 and 250 grams, and therefore the searching strategy was focused around the line of the highest probability resulting from our computations, the best wind model, and bordered by these mass limits. The reality exceeded all our expectations. The first meteorite with mass of 150 grams was found 97 m southward from the central line (it was found in the end of the first searching day of the first searching trip!), and the second meteorite with mass of 174 grams was recovered only 39 m northward from the central line. The distance between them was 275 m. Both were recovered in the middle part of the predicted mass range area, and not far from the landscape structure named Bunburra Rockhole. Therefore this meteorite fall is designated as the Bunburra Rockhole. Detailed description of the meteorite, classified as a basaltic eucrite, and basic orbital data of the rare Aten type orbit, and following analyses are in [8].

Conclusions: This result is exceptional from many aspects. It is the fifth predicted meteorite fall in history, and the first one based only on data from dedicated instruments. There was no other observation, and without our unique experiment the fall would be completely unknown. It is the first known meteorite from Aten type orbit, the first achondrite with known orbit, and the first instrumentally observed meteorite fall in the southern hemisphere. It is the first meteorite recovery based on data from the new instrument - AFO/DFO. It is clear proof and justification of our methodological approach - only high resolution observations could yield such good impact position data, even for a relatively unfavorable case. And finally, it is the first documented meteorite fall from a relatively small meteoroid, which produced not so bright fireball with a terminal height of 30 km.

Our general conclusion is that this project in the remote and hostile enviroment of the Australian desert is meaningful, and that these observations can bring data of fundamental value to solar system research. We also proved the correctness of our observational and computational methods and models.

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