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Slovakian part of the European fireball network

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Abstract. The successful photography and find of the Příbram meteorites in 1959 (Ceplecha, 1961) was an impetus for establishment of an all-sky photographic cameras network for monitoring fireballs and recovery of possible meteorites in Czechoslovakia of which part was also a network located in Slovakia. Since 1964 there have been at the territory of Slovakia successively set into operation all-sky photographic cameras at Banská Bystrica, Hurbanovo, Močiar, Modra, Piešťany, Rožňava, Skalnaté Pleso, Somotor, Stropkov and Trenčianske Stankovce. Maximum eight stations from the ten mentioned above operated simultaneously. Basic data concerning position and instrumentation, operating time and observational results are summarized and presented. There are only two stations operating in the network at present – at the observatories of the Astronomical Institute in the High Tatras and at the Comenius University Observatory in Modra.

Key words: meteor – fireball – meteorite

1. Standard cameras

In the territory of Slovakia there is located the most eastern part of the EN fireball network which was build up almost simultaneously with the whole network. The first two stations were put into operation already in October 1964 and the whole Slovakian part was completed in July 1969, when its eighth station started a routine work. The instruments and method of observation were similar to those originally designed by Zdeněk Ceplecha in founding this network in Czechoslovakia (Ceplecha and Rajchl, 1965).

An impetus for establishment of the all-sky photographic cameras network for observations of fireballs was the successful photography and find of the Příbram meteorites in 1959 (Ceplecha, 1961). The exposures were taken on 36 × 24 mm frames by standard commercial cameras with lens Flexon 50/2, viewing down on a convex spherical mirror in which the whole sky was displayed (Fig. 1).

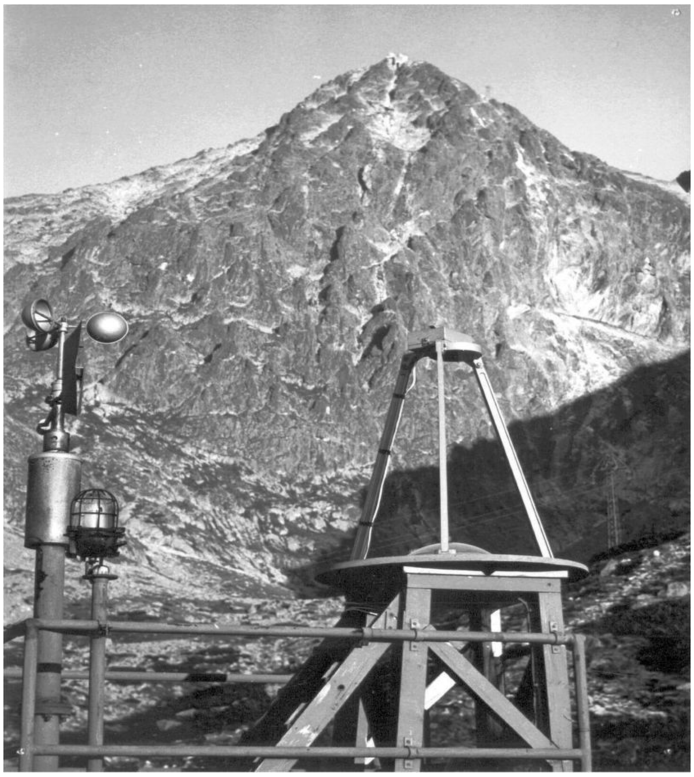

Figure 1. The all-sky photographic camera at the Skalnaté Pleso Observatory.

A small part of the sky around the zenith and in three narrow strips were obscured by the camera holder. A drawback of stations equipped in such a way was not having a device for meteor timing required for determination of a radiant and a heliocentric orbit. The time of appearance of a meteor was obtained from casual visual observations only, except for the western part, where the moving camera at the Ondřejov Observatory could still take photos of meteors (with a practical limit at 20 deg E longitude) and, hence in most cases only atmospheric trajectories and geocentric velocities could be determined. Later, the cameras were replaced by a new type: Zenit E with objectives Helios-44-2, f/2, 58 mm focal length. A mean distance between the stations (Fig. 2) was about 95 km.

The total search area within the borders of Slovakia is about 5×10^4 km^2; that was approximately 1/9 of the effective search area of the European Network. Of course, the cameras could see across the borders of Slovakia into neighbouring countries; a good example is the Turji-Remety bolide (Fig. 4) photographed above the territory of the Ukraine in 2001.

The main purpose of building up the network was the possibility to ob-

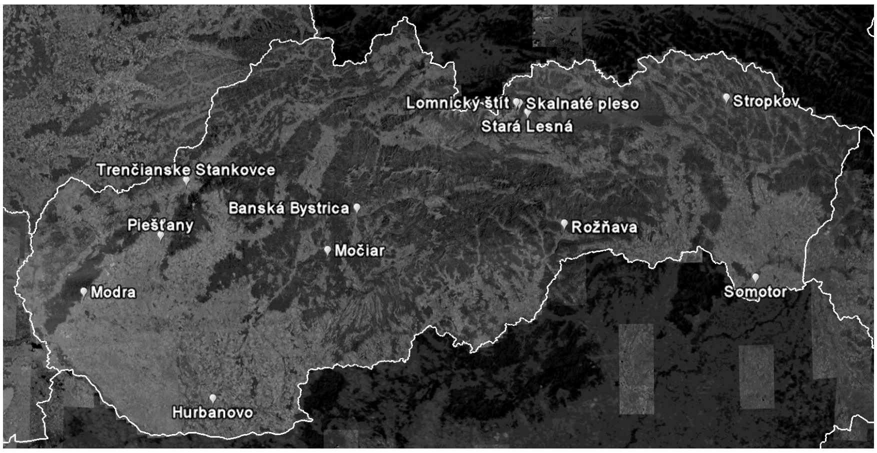

Figure 2. Locations of the all-sky cameras in Slovakia.

tain reliable atmospheric trajectories of very bright fireballs with prospects of searching casually for meteorites. Taking into account approximate statistics of meteorite falls of existing three fireballs networks those times (EN, MORP and Prairie Network) of the influx rate of meteorite-producing meteoroids of $4 \times 10^{-10}\,\mathrm{km}^{-2}\mathrm{h}^{-1}$ (Halliday, 1973), it would mean an attempt of a search for a meteorite in the Slovakian part of the EN should occur approximately once in 30 years. Moreover, the territory of Slovakia has an elongated shape and more than one half of the country is covered by mountains and woods, with adverse conditions for searching for meteorites. In the first ten years of operation, to obtain more effective results, the network was rebuilt and some stations were transferred to other locations removed from light polution areas.

Incidentally, after almost ten years of full operation, on May 27, 1979, there was a fireball of −12 maximum photographic magnitude recorded over Slovakia. The fireball was detected by two Slovak stations (Trenčianske Stankovce and Stropkov), one Czech and two Austrian stations. The initial mass of the meteoroid of about 220 kg ablated to a terminal mass of order of kilograms and fragmented to several pieces (Ceplecha *et al.*, 1980). The calculated site of the fall of the main piece of about 1 kg was the town of Zvolen with a probable search area of 10 km^2. A total of four expeditions were organized to find the meteorite, but without any success.

2. Fish-eye cameras

To make the program more effective, it was desirable to obtain not only atmospheric trajectories but also heliocentric orbits, which required to provide stations with a device for meteor timing, as well as to move some of them to places with better observing conditions. At the same time it was necessary to remove difficulties connected with a supply of new mirrors, quality of their surfaces and necessity of frequent coating (every 3–4 months). Therefore, at the end of the eighties the network went through a second reconstruction and mirrors were replaced by a direct photography of the sky. The stations equipped with fixed all-sky mirror cameras providing a positional accuracy of about 0.1 degree were replaced by fish-eye cameras (f/3.5, f = 30 mm) giving a positional accuracy of about one minute of arc (Ceplecha *et al.*, 1987). Results obtained also by the all-sky mirror cameras of the Slovakian part of the EN were published by Ceplecha *et al.* (1980, 1983 and 1987).

The commercial cameras were replaced by fish-eye cameras (Opton-Distagon, f = 30 mm) enabling a direct photography of the whole sky on a 9 × 12 cm planfilm, removing thus the problems with the mirror and substantially increasing the accuracy. The cameras were put at the observatories of the Astronomical Institute in the High Tatras (Skalnaté Pleso – 49°.2 N, 20°.2 E, 1 788 m) and at the Astronomical and Geophysical Observatory of the Comenius University in Modra (48°.4 N, 17°.3 E, 530 m). Consequently, the operation of all remaining mirror cameras was successively stopped. Thus there are only two fish-eye bolide stations operating in the Slovakian part of the network at present.

The Modra Observatory fireball station was build up in 1993 and consists of two fish-eye cameras equipped with Opton Distagon 3.5/30 mm optics. One camera is operated in a fixed mount mode, while the other moving camera follows rotation of sky. This provides a possibility of determining the time of appearance of photographed meteors. The fixed camera is equipped with a rotating shutter for velocity measurements.

The most successful exposure made at Modra was a record of the 1998 Leonid meteor shower activity burst in the night on November 16/17, where on the guided camera exposure over the time of four hours (23:33:00 – 03:37:10 UT) 156 bolides were recorded (Fig. 3). Only about half of these were also recorded by the fixed camera. As on November 16/17 it was cloudy in most parts of Europe, the Modra station remained the only one from the European Fireball Network were this unique phenomenon was recorded (Tóth *et al.*, 2000). Altogether of about 1 500 expositions were taken at Modra station since 1991.

Skalnaté Pleso station has been operating already since 1964 and the mirror camera was replaced there by the fish-eye camera in 1986. In a total more than 2 900 expositions have been taken at the station since 1964. Among them one significant and the most spectacular event was recorded on November 17, 2001 – flight of the Turji-Remety bolide (Fig. 4). The flight was recorded by both Slovak stations (Modra and Skalnaté Pleso) and two Czech stations (Lysá hora and Telč) used for calculations. Out of the four stations, Skalnaté Pleso was the closest one to the fireball flight followed by an expected fall of a meteorite (Spurný and Porubčan, 2002). The fireball flew over western Ukraine in direction to Slovakia, entered the atmosphere at a velocity of 18.5 km s^{-1} and began its luminous path of 106 km at a height of 81 km. The maximum brightness

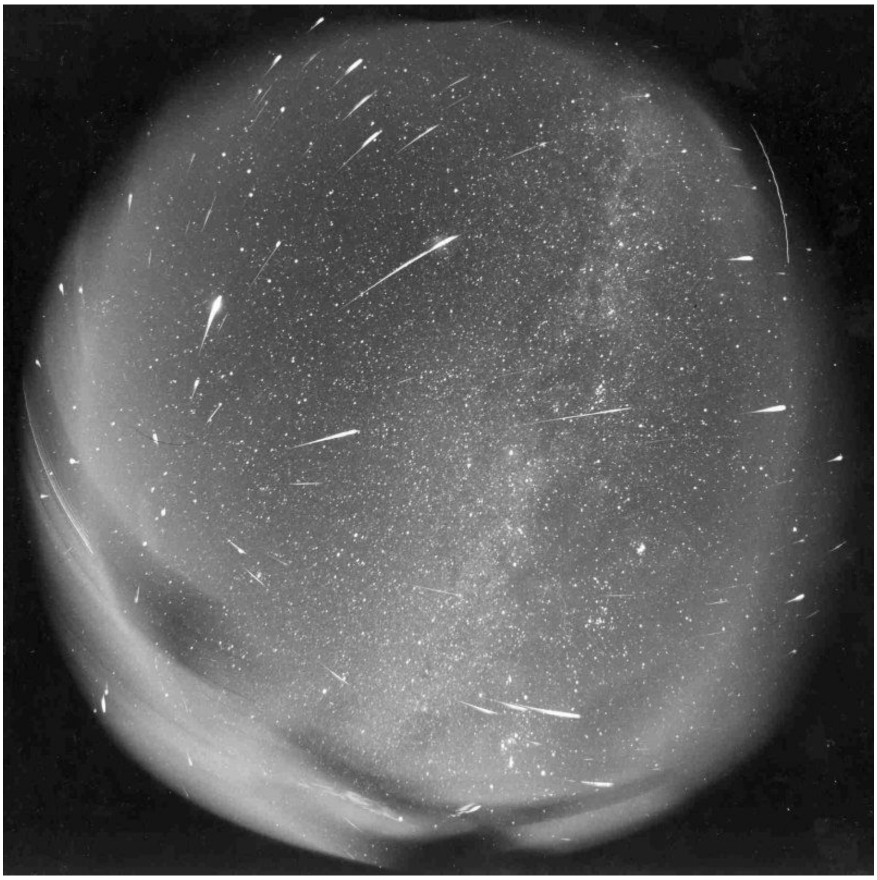

Figure 3. The photo obtained at Modra Observatory during the peak of the Leonids 1998 activity (guided camera, exposure: November 16, 23:33:00 – November 17, 03:37:10 UT).

of the absolute photographic magnitude −18 reached at a height of 25 km, terminated at 13.5 km near the Ukrainian village of Turji-Remety, which means that it was the deepest ever photographically recorded fireball in history. The calculated initial dynamical mass of the meteoroid was about 4 300 kg, some part of it survived the flight through the atmosphere and dropped on the ground. The computed terminal mass was of the order of hundred kilograms. From many visual observations, three main pieces were observed until the end of the luminous trajectory, which corresponds with the calculations and it is highly probable that the terminal masses of the pieces could reach over 100 kg each. Several expeditions were organized to recover the meteorites, but so far without

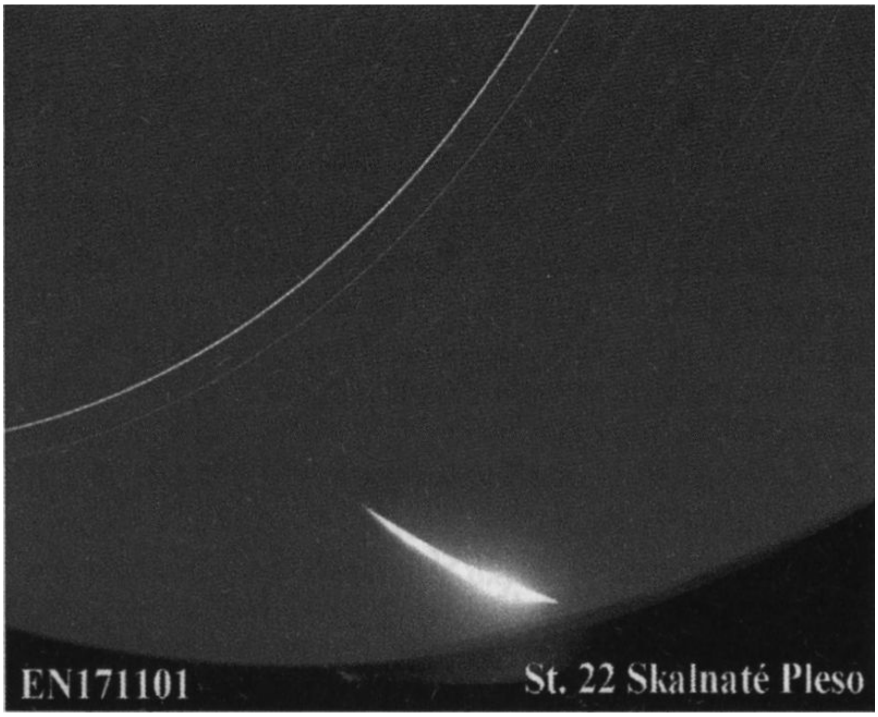

Figure 4. A record of the EN171101 (Turji-Remety) bolide by the fish-eye camera at Skalnaté Pleso.

any success.

Another successful record of a bright bolide over Slovakia of −11 maximum photographic magnitude recorded by one Slovak (Skalnaté Pleso) and four Czech stations was obtained on October 23, 2006 – the EN231006A (Spurný, 2006). The bolide ablated to terminal mass of about 0.15 kg. The calculated site of the fall of fragments was the village of Šášovské Podhradie (near Žiar nad Hronom, Middle Slovakia). However, the meteorites were not found.

A disadvantage of the Skalnaté Pleso position is a close mountain range shielding the western horizon (the preferred direction where other stations of the EN are located) up to an elevation of 22 degrees. Therefore, it was decided to move the station at Lomnický Štít (2 636 m above sea level; the two sites being only 1 km apart) the site of the coronal station of the Astronomical Institute of the Slovak Academy of Sciences (Svoreň *et al.*, 2008). The new station having thus the ideal horizon started its operation in October 2007 and it is equipped with an Autonomous Fireball Observatory of the Astronomical Institute of the Academy of Sciences of the Czech Republic (Fig. 5). These cameras have been utilized in the Czech part of the EN for several years. From a long term study of

Figure 5. The autonomous camera at the Lomnický Štít.

the climate at the Lomnický Štít it was evident that a majority of clear nights and exposures can be expected in winter, when longer periods of inversion are more frequent. This advantage is superimposed by the fact that the adjacent station in the Czech Republic, Lysá hora, which is in a favorable distance from the Lomnický Štít of 80 km to the west, is also above the inversion because it is located in the mountains on the highest top of the Beskydy Mountains (1 324 m above sea level). The camera has an internal heating important at almost arctic winter period conditions at the peak. The station is under a steady check by the staff of the close coronal station. The first test winter period (from 2007 October to 2008 February) clearly demonstrated an ideal position of the station at the peak. However, during summer thunderstorms are frequent events in the High Tatra Mountains and an effective grounding of sensitive electronic devices, that are parts of the Autonomous Fireball Observatory, is very difficult or even impossible at the height of the peak. Therefore, during summer periods the camera is moved down to Stará Lesná Observatory (49°.2 N, 20°.3 E, 812 m, 7 kilometers apart from the Lomnický Štít).

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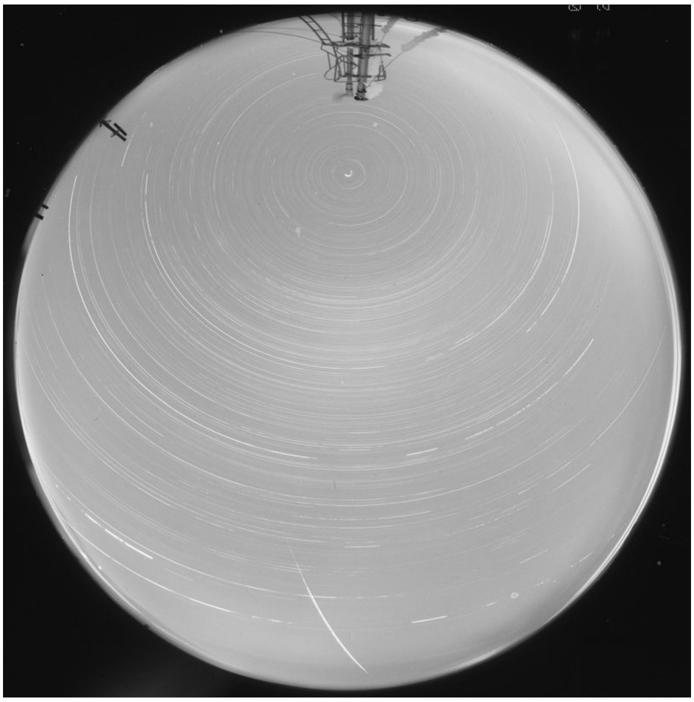

Figure 6. The first Lomnický Štít's bolide of Dec. 7, 2007.

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