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FIRST RESULTS OF BOSNIA-HERZEGOVINA METEOR NETWORK (BHMN)

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Abstract. Modeled according to similar networks in the region, since the spring of 2013 in Bosnia and Herzegovina began operation of video meteor network, which currently consists of five stations. In preparation is expansion of the network by setting up another 5 stations. The Network is jointly managed by Astronomical Society Orion Sarajevo and Federal Hydrometeorological Institute in Sarajevo whose meteorological stations were used for installation of cameras. So far cameras of BH meteor network recorded over 9614 meteors and we calculated 1306 orbits. In this paper we present the results of the first year of operation of our meteor network and analysis of Geminids recorded during the peak of this meteor shower that occurred 12/13th December 2013., which confirms the high quality of the data obtained. The orbits obtained with the help of stations of our Network were compared to the orbits of the Geminid meteors obtained by Japanese video meteor network (SonotaCo) and the orbit of the presumed parent body of the shower - asteroid 3200 Phaethon, using Southworth-Hawkings D-criteria.

1. INTRODUCTION

Seen from the Earth, meteors are local phenomenon, i.e. meteors are visible only from a small region on the planet, below the point at which they start to burn. They are formed by penetration of small bodies from interplanetary space into the Earth's atmosphere at high speed whereas the friction with the upper atmosphere leads to ionization and heating of the air and at altitudes of about 100 km, the track due to their passage, becomes visible. In the classical era, meteors were observed visually, photographically or by radars.

The emergence of low-cost video camera has opened possibility of a very high quality monitoring of these phenomena with previously unimaginable precision. The basic operation of one meteor network consists of making video recordings of meteors, simultaneously with at least two separated video cameras. On this basis it is possible to determine the atmospheric trajectory of the meteor shower and its speed in each frame of video. Knowledge of this speed allows us to calculate the velocity and heliocentric orbits of meteoroid particles before the collision with the Earth, which in some cases receive its origin and relationship with the parent comet or asteroid. The Bosnia-Herzegovina meteor network (BHMN) has been created and developed in the preceding two years by Astronomical Society Orion Sarajevo and their cooperation with the Federal Hydro meteorological Institute.

2. STATIONS AND EQUIPMENT

Many CCTV cameras for video surveillance in low light conditions have sufficient sensitivity to, with high-quality lens and the field of view of the order of 80x60 degrees, detect stars up to magnitude 4. After a certain period of testing various models, we acquired 7 cameras from manufacturer iDEA Classic from Croatia (model DVC-CAM SM234LX-Ex) and 3 cameras from manufacturer KT & C of Korea, (model KPC-350BH). Both types of cameras use highly sensitive Sony Super HAD CCD chip. For all these cameras we purchased Tokina Lenses from Japanese manufacturer, model TVR0398DCIR. Specifications of the chips and camera lenses are given in Tables 1. and 2. below.

Figure 1: Two types of cameras and Tokina lens.

model	format	system	chip
DVC-CAM-SM234LX-Ex	1/3"	PAL 25 fps	ICX255AL
KPC-350BH	1/3"	NTSC 29.97 fps	ICX254AL

model	TVR0398DCIR
Focal length	3 - 8.2 mm manual
F number	0.98
Iris	automatic

Each station consists of a computer, UPS and camera placed in a classical frame of surveillance cameras with heating and front window. Internet connection and electric power are necessary. Computers must be Pentium IV-2 GHz because of the processor power required for further analyze of video records.

In cooperation with the Federal hydro meteorological Institute Federation of BiH, so far we have set up five permanent stations, mainly on buildings of existing hydro meteorological stations in various cities in BiH. One is on a private house in Croatia.

3. ACQUISITION AND PROCESSING

The cameras are monochromatic and have an analog output, so for a digitization and recording we need the TV card with video input or a special video grabber. The acquisition of data or recording a meteor from the digitized video is done with the help of a software package UFO produced by Japanese meteor network SonotaCo[1]. This package consists of 3 programs: UFOCapture - to record meteors, UFOAnalyzer - to calibrate the camera field of view and measuring meteor coordinate in every frame of video and UFOOrbit - to compute the atmospheric trajectory and orbit of simultaneously recorded meteors. To search for a simultaneous meteor in video over various cameras is essential that the system clocks of computers at each station synchronized at the same time. This is done with the help of Dimension 4 which adjusts the system time of computers over the Internet with the time of servers every minute. UFOCapture: monitors digital video camera frame by frame, calculates the average brightness value of all pixels in each frame, sets a certain brightness threshold that should be exceeded by a certain number of pixels in a certain number of successive frames and such significant change is the trigger for video recording. In doing so, the software can tune the parameters that will shut off the recording of transient flashes, slow moving objects like airplanes or such changes in which the resulting trajectory in the sky is too curved to be a meteor. The program may store in a buffer a given number of frames so that together with the appearance that triggered the recording he can capture a certain number of frames before and after the termination of this phenomenon. Along with the video text log file is recorded which specifies the coordinates of pixels in which there was a shift for each frame, the number of pixels in which there was a shift, the moment at which it happened and some data related to that video. In addition, as in the field of view of the camera there are stars, which also have the brightness above average, the program identifies and captures their positions in a bitmap image (scintillation mask), which is then used to analyze the video.

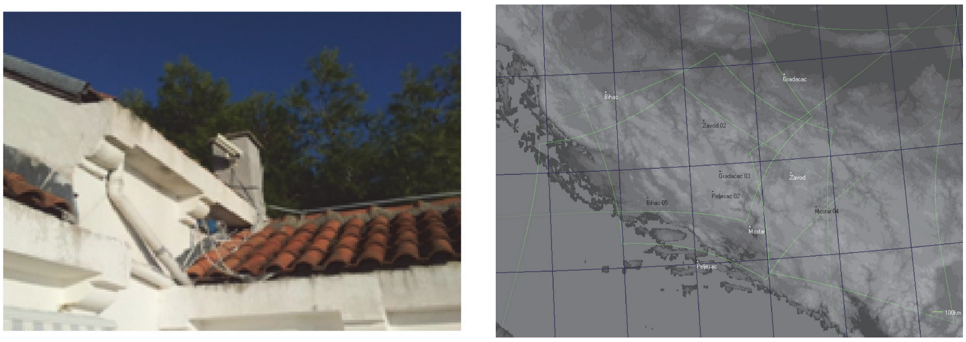

Figure 2: Southern camera in Lovište, Pelješac, Croatia.

location	lat (°)	E long (°)	alt (m)	resolution	FOV (°)	azimuth (°)	elevation (°)	'/ pixel
Pelješac	43.0272	17.0318	10	704x528	80x60	15.07	47.16	7
Bihać	44.8078	15.8667	301	704x528	80x60	160.37	37.66	7
Gradačac	44.87	18.45	230.5	704x528	80x60	217.15	31.2	7
Mostar	43.3483	17.7933	97	704x528	70x52	78.81	51.29	6
Sarajevo	43.8676	18.4228	631	720x480	90x68	309.57	36.71	7.5

In the clear night, in the camera field of view of 80x60 degrees, it is possible to see between 50 and 200 stars up to magnitude 4. These stars are used to calibrate the camera field of view in the program UFOAnalyzer. What is recognized as a star is overlapped manually with the positions of stars visible at a given time at a given position in the area of the sky. For this, software uses a catalogue that is in the program UFOAnalyzer. This allows roughly to locate the camera orientation, and then automatically the software connects all the other stars with coordinates from the catalog and compute constants of plate. In a large field of view there can be a significant distortion and in these calculations software going to the coefficients of the fourth order. Ultimately, this yields the equation which can be used for any of the coordinates (x, y) on the video frames to get the celestial coordinates of a given pixel or in the local horizontal either in the equatorial coordinate system, where the equatorial coordinates included atmospheric refraction. This, together with geographical coordinates of the stations, field of view and resolution of the camera, is saved as the camera profile and will be used for further analysis of the images of the meteor.

After each night of recording, the records are manually checked in order to remove objects which are are not meteors, and UFOCapture has not rejected them. These can be insects or birds that flew very close to the camera. Then, each meteor record is passed through an analysis in which in every frame of video is determined the position of meteor and recorded as a horizontal and equatorial coordinates, together with the number of pixels covered by a meteor and the overall brightness of these pixels. Finally the fitting of these positions with a large circle on the celestial sphere is made, and as a result we get a clip of the large circle that corresponds to the apparent trajectory of meteor on the celestial sphere. For each meteor all of this together with the coordinates of station is saved in one file, which is output of the analysis. Results for all meteors from a certain time interval, e.g. one night, you can save in the form of an Excel spreadsheet in which are written only the data that are relevant for calculating atmospheric trajectories and orbits, and this are data which are connected to clip of the great circle which corresponding to meteor trace, data on average angular velocity, time of occurrence and duration of meteor and position of the station.

After the processing of records from individual stations, the results are collected in one place in the program UFOOrbit. This software primarily checks whether among the recorded meteors from all stations are those that were recorded simultaneously with two or more stations, under certain time tolerance. If that is the case, next procedure is computing of atmospheric trajectory and orbit. UFOOrbit for calculation of atmospheric trajectory and orbit in Solar system use so-called Method of planes (described in paper of Zdenek Ceplecha from 1987 year [2]) in which, due to their very short duration, meteor trajectories considered rectilinear. Finally all parameters meteors are compared with parameters of known meteor showers and in the case of a match, meteor is associated with a given shower. UFOOrbit gives a graphical representation of the heliocentric orbit and projection of the atmospheric trajectory on the Earth's surface. The quality of the obtained orbit, i.e. uncertainty of the orbital elements and atmospheric path, depends significantly on the geometry of the certain case and the duration of the meteor. Best orbit are obtained in the case that the angle between the geometric planes of two stations is near 90 until the speed of the meteor is determined better if his duration is longer. Because of this UFOOrbit classifies orbits towards certain parameters of quality. The best orbits are called Q3 orbits.

4. SHOWERS STATISTICS AND SPECIAL CASES

In the whole period of our meteor activity, up to August 2014, cameras of Bosnia and Herzegovina meteor network recorded a total of 14,792 meteors, of which 2349 are recorded simultaneously with two or more cameras so they have calculated orbits.

Recorded meteorites are from all major showers and data about them are given in Table 4. From the calculated orbits, 329 are a high quality (Q3) according to the parameters of software UFOOrbit and projections of atmospheric trajectories of these meteors are given in Figure 4.

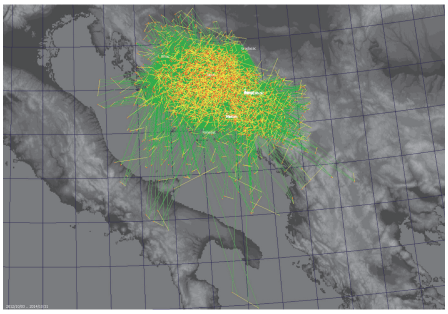

Figure 3: The ground projection of recorded meteors.

meteor shower	number of meteors	number of orbits	orbits
Orionids 2012.	286	33	2
Perseids 2013.	663	84	7
Orionids 2013.	333	47	3
Geminids 2013.	1081	202	52
Perseids 2014.	1978	410	56

We recorded a few very long meteors, earth grazers, 4 of them are longer than 100 km, and the longest had atmospheric path of 154 km. The vast majority of meteors have duration of less than 0.5 s, while during the entire operation of the network we recorded 44 meteors with duration of more than 1 second. It was recorded few fireballs - bright meteors whose flight was accompanied by explosions, some of which have absolute magnitudes greater than -5. Until now, the brightest fireball was captured on 01.11.2013. at 23:36:59 UTC and recorded by 3 station of BH network, 2 stations of Croatian Meteor Network and one station of Italian meteor network. His flight lasted longer than 3 seconds and started at an altitude of about 90 km and ended at about 34 km above the Zenica. According to the analyzes who are still in progress, absolute magnitude stood between -8 and -9, and it is possible that the initial mass of the object that caused it was over 10 kilograms.

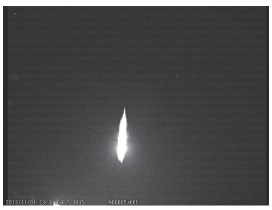

Figure 4: Bright fireball captured on 01.11.2013. from Sarajevo, Pelješac and Gradačac stations.

n	Sol	a	q	e	i	ω	Ω	α	δ	Vg	D_{SH} S	D_{SH} P
1	261.737	1.218	0.145	0.881	21.36	325.19	261.74	113.73	31.82	32.99	0.03	0.03
2	261.766	1.199	0.151	0.874	22.25	324.67	261.77	113.94	32.5	32.66	0.017	0.033
3	261.818	1.279	0.139	0.891	24.71	325.31	261.82	114.35	32.68	34.06	0.043	0.049
4	261.821	1.294	0.151	0.884	22.79	323.64	261.82	113.14	32.62	33.49	0.005	0.041
5	261.825	1.284	0.147	0.886	21.39	324.27	261.83	113.06	31.86	33.45	0.024	0.035
6	261.859	1.334	0.143	0.893	21.71	324.29	261.86	112.92	31.75	34	0.021	0.031
7	261.877	1.301	0.154	0.882	22.5	323.16	261.88	112.91	32.67	33.38	0.012	0.046
8	261.879	1.322	0.146	0.89	23.28	324.06	261.88	113.33	32.49	33.96	0.013	0.038
9	261.884	1.26	0.147	0.883	21.93	324.43	261.88	113.48	32.11	33.29	0.016	0.03
10	261.891	1.422	0.139	0.902	24.29	324.19	261.89	113.16	32.4	34.99	0.035	0.049
11	261.893	1.235	0.149	0.88	21.81	324.51	261.89	113.65	32.17	33.01	0.019	0.031
12	261.907	1.295	0.146	0.888	23.37	324.31	261.91	113.63	32.54	33.77	0.015	0.036
13	261.917	1.229	0.146	0.881	21.02	324.91	261.92	113.66	31.72	33	0.034	0.033
14	261.935	1.231	0.154	0.875	22.18	323.89	261.94	113.59	32.59	32.8	0.014	0.039
15	261.941	1.366	0.146	0.893	23.51	323.61	261.94	113.06	32.56	34.26	0.017	0.043
16	261.947	1.291	0.145	0.887	21.86	324.37	261.95	113.32	31.95	33.61	0.018	0.029
17	261.95	1.364	0.146	0.893	22.71	323.69	261.95	112.9	32.24	34.19	0.01	0.037
18	261.978	1.331	0.14	0.895	22.72	324.76	261.98	113.5	31.93	34.22	0.021	0.026
19	261.989	1.376	0.143	0.896	23.06	324.02	261.99	113.1	32.18	34.44	0.016	0.035
20	261.992	1.277	0.146	0.886	22.65	324.48	261.99	113.71	32.27	33.57	0.012	0.028
21	262.012	1.32	0.148	0.888	22.72	323.8	262.01	113.25	32.37	33.8	0.005	0.035
22	262.014	1.226	0.157	0.872	22.42	323.56	262.01	113.66	32.85	32.65	0.016	0.043
23	262.018	1.279	0.149	0.883	22.1	324.01	262.02	113.41	32.24	33.38	0.012	0.032
24	262.023	1.423	0.146	0.897	23.53	323.14	262.02	112.73	32.52	34.61	0.022	0.048
25	262.029	1.305	0.147	0.887	23.16	324.04	262.03	113.56	32.51	33.77	0.011	0.035
26	262.167	1.229	0.147	0.881	22.5	324.81	262.17	114.29	32.29	33.12	0.02	0.025
mean		1.296	0.147	0.887	22.597	324.198	261.926	113.424	32.301	33.634	0.018	0.036
std.	dev.	0.061	0.004	0.007	0.875	0.559	0.094	0.407	0.315	0.612	0.009	0.007

During the flight, it happened few explosions and there is a possibility that some of the fragments survive atmospheric flight and fell near Zenica. Another bright fireball was captured on September 13th 2014. at 00:54:41 UTC and recorded by 3 station of BH network. His flight lasted longer 6 seconds (the longest duration up to now) and started at an altitude of about 85 km over Travnik and ended at about 44 km above the Gradačac. During his flight, it happened at least 5 explosions and there is a possibility that some of the fragments survive atmospheric flight and eventually fell in Posavina region on the border between Bosnia and Croatia.

In the study of the small bodies of the Solar system, in particular, meteor showers, the most commonly used criterion of mutual associations of orbits of small bodies and their belonging to the same shower or their associations with some parental body is called Southworth-Hawkings criteria [3]. This criterion uses the orbital elements of the body and defines the "distance" between two orbits as:

$$
\begin{aligned}
D_{SH}^2 \; &= (e_B - e_A)^2 + (q_B - q_A)^2 + \left[2\sin\frac{(i_B - i_A)^2}{2}\right]^2 \\
&+ \; \sin i_A \sin i_B \left[2\sin\frac{(Q_B - Q_A)^2}{2}\right]^2 + \left[\frac{e_B + e_A}{2} 2\sin\frac{(Q_B + \omega_B) - (Q_A + \omega_A)}{2}\right]^2
\end{aligned}
$$

DSH value, below which, the two orbits are considered to belong to the same meteor showers various authors have taken a different values, and can be assessed for showers with known parent bodies. For Geminids, who are a very young shower with well-defined orbits and very sharp peak of activity, DSH is one of the smallest. To investigate the quality of the data that we get, thanks to very favorable weather conditions that we had during the peak of the Geminids in December 2013, we decided to compare the orbits that we get with the orbits of the data base of the Japanese meteor network SonotaCo and with orbit of assumed parental body of Geminids - asteroid 3200 Phaethon. The table 5 shows the orbital elements for 26 Geminids recorded on the night of their maximum December 13/14. 2013. For this analysis only the highest quality meteors were selected (Q3 criterion of program UFOOrbit).

5. CONCLUSION

The activities so far carried out in Bosnian and Herzegovinian meteor network showed extreme usability of cheap video surveillance equipment for recording meteors which allows serious research in this field. The results we get (and we will get in the future) with this the equipment and methods, will enable various statistical studies of meteor showers. In addition, as a patrol network that captures every clear night, one such meteor network will soon or later register fireballs that will survive atmospheric flight and fall as meteorites. After the analysis of these recordings it will be possible to calculate the site of crash. We have plans to expand our meteor network by setting up new stations that will allow more quality results. Finally it is very important educational aspects of this work. In activities of this network we may include secondary schools pupils or students of natural sciences who can conduct an initial analysis which allowing them first experiences in serious scientific research.

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