First results of Bosnia-Herzegovina Meteor Network (BHMN)

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Inspired by similar networks in the region, a video meteor network began since the spring of 2013 in Bosnia and Herzegovina which currently includes eight stations. Further expansion of the network is under preparation by setting up another 2 stations. The Network is managed by the Astronomical Society Orion Sarajevo together with the Federal Hydrometeorological Institute in Sarajevo whose meteorological stations were used for the installation of the cameras. By mid-June 2015 the cameras of the BH meteor network had recorded over 20000 meteors and we had calculated more than 4000 orbits. In this paper we present the results of the first two years of operation of our meteor network.

1 Introduction

The Bosnia-Herzegovina meteor network (BHMN) has been created and developed in the previous three years as a result of the work of members of the Astronomical Society Orion Sarajevo and their cooperation with the Federal Hydrometeorological Institute in Bosnia and Herzegovina. In the first phase (August 2012 – May 2013) we tested many CCTV cameras, housings, locations and software. In May 2013., we started to set up the permanent stations in BiH and neighboring countries. In this paper we present the first results of the BiH meteor network.

2 Stations and equipment

Many of the CCTV cameras in use today for video surveillance in low light conditions have sufficient sensitivity to detect stars up to an apparent magnitude of +4, using a high-quality lens with a field of view in the order of 80x60 degrees. Astronomers recognized these opportunities and many models of these cameras are being used to monitor star occultations by asteroids and also for capturing meteors. After a certain period of testing various models, we acquired 7 cameras from the manufacturer “iDEA Classic” from Croatia (model DVC-CAM SM234LX-Ex) and 3 cameras from the manufacturer KT & C from Korea, (model KPC-350BH). Both types of cameras use a highly sensitive Sony Super HAD CCD chip. For all of these cameras we purchased lenses from the Japanese manufacturer Tokina, model TVR0398DCIR. Specifications of the chips and camera lenses are given in *Table 1*. and *Table 2*. below.

Each station consists of a computer, UPS and a camera placed in a housing with heating in front of the window. In cooperation with the Federal Hydrometeorological Institute of the Federation of BiH we have set up eight permanent stations so far, mainly on buildings of existing hydrometeorological stations in various cities across BiH. One is at a private house in Croatia. Basic information about all the locations of stations, orientation, field of view and precision of the cameras are given in *Table 4*. A map of the sky coverage of the BiH stations at an altitude of 100 km is shown in *Figure 2*.

Figure 1 – Two types of cameras and the Tokina lens.

Table 1 – Specifications of the chips of the cameras.

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

Table 2 – Specifications of the camera lenses.

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

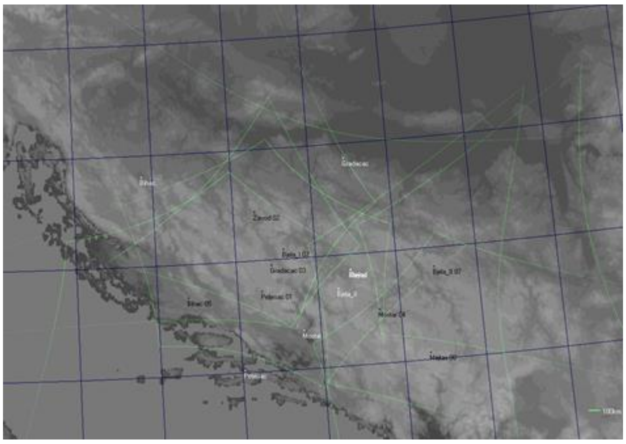

Figure 2 – The map of the sky coverage of the BiH stations at an altitude of 100 km.

3 Acquisition and processing

All cameras are monochromatic and have an analog output, hence for digitization and recording we need a TV card with video input or a special video grabber. We have various models PCI TV cards in our computers, most of them from the manufacturers Hauppauge and EasyCap USB video grabbers. The acquisition of meteor data captured by a digitized video is done with the software package *UFO* produced by the Japanese meteor network SonotaCo[1]. This package consists of three programs: *UFOCapture* – for the recording of meteors, *UFOAnalyzer* – for the calibration of the cameras fields of view and the measurements of the meteor coordinates in each frame of the video and *UFOOrbit* – to compute the atmospheric trajectory and orbit of simultaneously recorded meteors. To search for a simultaneous meteor in a video among various cameras it is essential that the system clocks of the computers at each station is synchronized. This is done with the help of the *Dimension 4* software which adjusts the system time of computers via the Internet synchronized every minute with time servers.

The software *UFOOrbit* uses the so-called “Method of planes” (Ceplecha, 1987) to calculate the atmospheric trajectory and orbit in which, due to their very short duration, the meteor trajectories can be considered rectilinear. The quality of the orbits obtained, i.e. the uncertainty of the orbital elements and atmospheric path, depend significantly on the geometry of the specific case and the duration of the meteor. The best orbits are obtained in the case that the angle between the geometric planes of the two stations is near to 90° and the velocity of the meteor can be better determined if the duration is long. Because of this, *UFOOrbit* classifies orbits according to certain quality criteria. The best orbits are the so-called Q3 orbits for which it is required that the angle between two planes is at least 15° and the duration is at least 0.3 seconds. In addition, the angular length of the meteor trail at both stations needs to be at least 3°, they should have at least a 50% of overlap and the difference in speeds calculated from each stations should not exceed 10%. There are also some other requirements concerning the height at which the meteor appeared, its geocentric velocity and the uncertainty in the determination of the radiant.

4 Shower statistics and special cases

During the period of our existence, up to August 2015, the cameras of the Bosnia and Herzegovina Meteor Network have recorded a total of 26978 meteors, of which 4670 have been recorded simultaneously by two or more cameras and have calculated orbits. The recorded meteors are from all major showers and their data are given in *Table 3*. From these calculated orbits, 694 are of highest quality (Q3) according to the parameters of the software *UFOOrbit. T*he projections of their atmospheric trajectories and orbits are given in *Figure 3and 4*.

A few fireballs have been recorded – bright meteors accompanied by explosions, some of which had an absolute magnitude brighter than -5. Until now, the brightest fireball was captured on 1 November 2013 at $23^h36^m59^s$ UTC, recorded by 3 stations of the BH network, 2 stations of the Croatian Meteor Network and one station of the Italian meteor network. It lasted longer than 3 seconds and started at an altitude of about 90 km and ended at about 34 km above the city Zenica. According to the analysis which is still in progress, the absolute magnitude was between -8 and -9 and the initial mass of the object may have been around 10 kilograms.

Table 3 – Numbers of recorded meteors for some major showers.

meteor shower	number of meteors	number of orbits	number of Q3 orbits
Orionids 2012.	286	33	2
Perseids 2013.	663	84	7
Orionids 2013.	333	47	3
Geminids 2013.	1081	202	52
Perseids 2014.	1988	410	56
Orionids 2014.	501	66	2
Geminids 2014.	1381	288	78
Perseids 2015.	1711	375	77

[1] http://sonotaco.com/e_index.html

Table 4 – Basic information about all the locations of stations, orientation, field of view and precision of the cameras.

location	lat (°)	E long (°)	alt (m)	resolution	FOV (°)	azimuth (°)	elevation (°)	'/ pixel
Pelješac	43.0272	17.0318	10.0	704x528	80x60	15.07	47.16	7.0
Bihać	44.8078	15.8667	301.0	704x528	80x60	160.37	37.66	7.0
Gradačac	44.8700	18.4500	230.5	704x528	80x60	217.15	31.20	7.0
Mostar	43.3483	17.7933	97.0	704x528	70x52	78.81	51.29	6.0
Sarajevo - Zavod	43.8676	18.4228	631.0	720x480	90x68	309.57	36.71	7.5
Sarajevo - Mejtaš	43.8620	18.4207	578.0	704x528	70x52	137.69	41.98	6.0
Bjelašnica I	43.7038	18.2571	2054.0	720x480	66x44	313.55	53.60	6.0
Bjelašnica II	43.7038	18.2571	2054.0	720x480	66x44	84.70	44.55	6.0

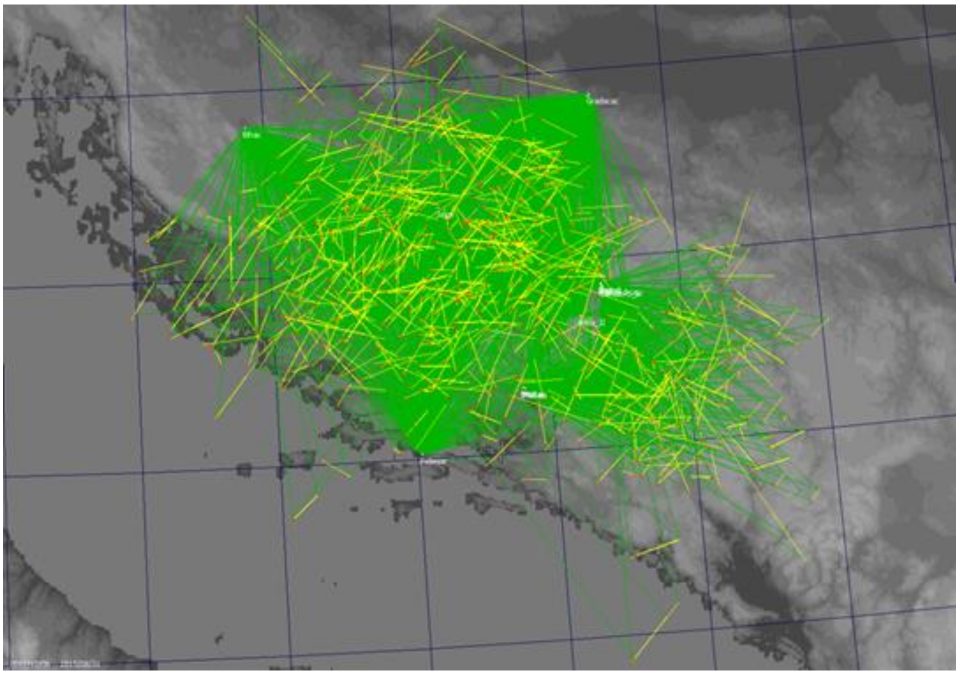

Figure 3 – Projection of the trajectories of 694 double station meteors with the highest accuracy Q3.

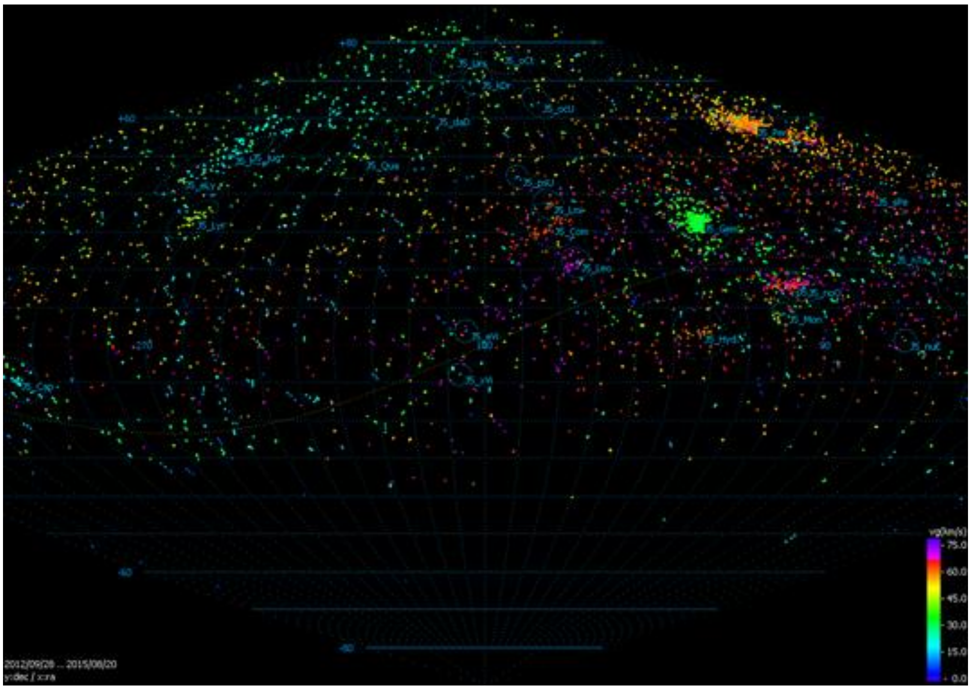

Figure 4 – Radiants of all recorded meteors.

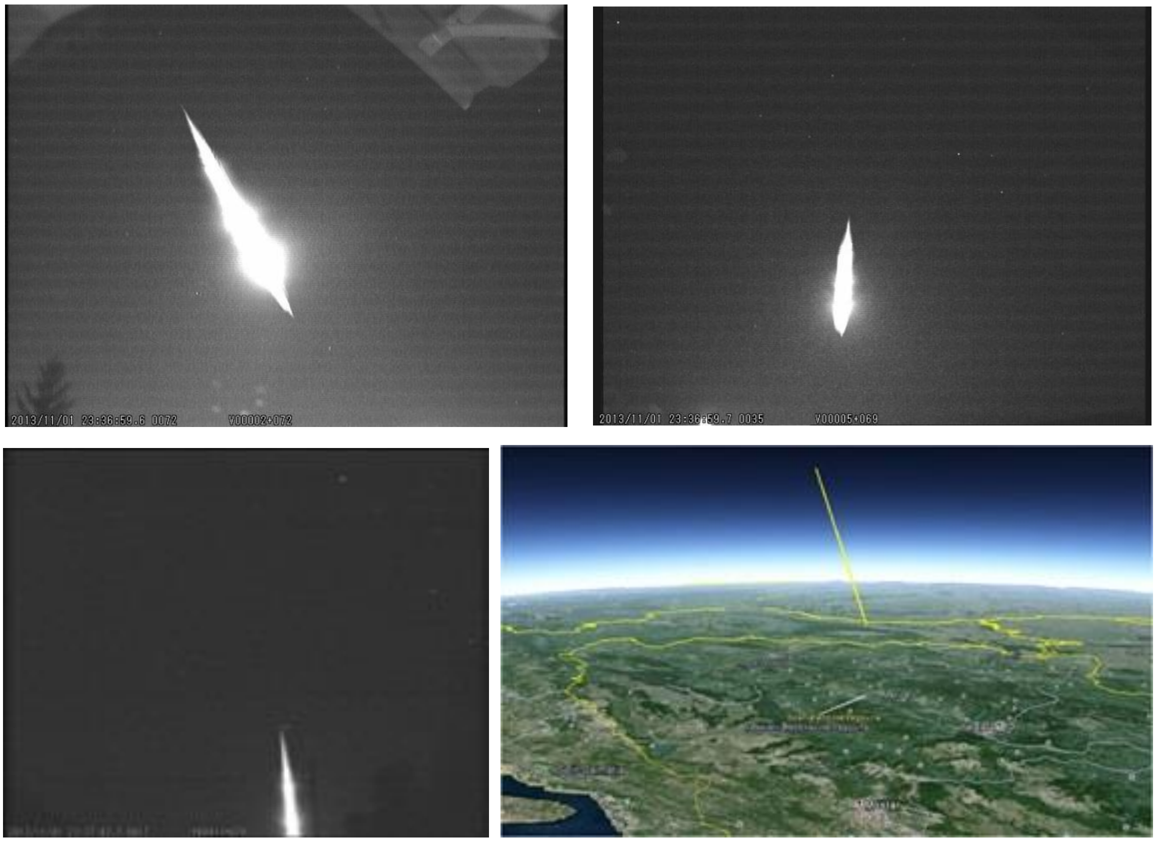

Figure 5 – A bright fireball captured on 1 November 2013. from the Sarajevo, Pelješac and Gradačac stations.

Another bright fireball was captured on September 13th 2014 at $00^h54^m41^s$ UTC by 3 stations of the BH network. It lasted longer than 6 seconds (the longest duration up to now) and started at an altitude of about 85 km over the city Travnik and ended at about 44 km above the city Gradačac. During its flight, it showed at least 5 explosions and there is a possibility that some of the fragments survived the atmospheric flight and eventually fell in the Posavina region near the border between Bosnia and Croatia.

5 Analysis of the Geminids 2013 and the Perseids 2014

In the study of the small bodies of the Solar system, in particular, meteor showers, the most commonly used criterion of mutual association of orbits of small bodies and their relation to the same shower or their associations with some parent body is called the "Southworth-Hawkings criteria" (Southworth and Hawkins, 1963). This criteria uses the orbital elements of the body and defines the "distance" between two orbits as:

$$D_{SH}^2 = (e_B - e_A)^2 + (q_B - q_A)^2 + \left[2sin\frac{(i_B - i_A)}{2}\right]^2 + sin\, i_A sin\, i_B\left[2sin\frac{(\Omega_B - \Omega_A)}{2}\right]^2 + \left[\frac{(e_B + e_A)}{2}2sin\frac{(\Omega_B + \omega_B) - (\Omega_A + \omega_A)}{2}\right]^2$$

Some authors have taken different D_{SH} value, below which two orbits are considered to belong to the same meteor showers or can be associated with a shower or with a known parent body. For the Geminids, which are a shower with well-defined orbits and a very sharp peak of activity, the D_{SH} value 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 our orbits with the orbits of the Japanese meteor network SonotaCo and with the orbit of the assumed parent body of the Geminids – asteroid 3200 Phaeton. *Table 5* shows the orbital elements for 26 Geminids recorded during the night of their maximum December 13–14 2013. Only the highest quality meteors were selected for this analysis (Q3 criterion in the program *UFOOrbit*). The Same procedure was applied to the 2014 Perseids, for which we present 20 Q3 orbits together. We compare these with the mean orbit by SonotaCo and the orbit of the parent comet 109P/Swift-Tuttle (*Table 6*).

6 Conclusion

The activities carried out so far by the Bosnia and Herzegovina meteor network showed the extreme usability of cheap video surveillance equipment for the recording of meteors which makes serious research possible in this field. The results we get (and which we will get in the future) with this equipment and methods will enable various statistical studies of meteor showers. In addition, as a patrol network that captures every clear night, our meteor network will sooner or later register fireballs that will survive their atmospheric flight and drop meteorites. After the analysis of such event it will be possible to calculate the site of fall. We have plans to expand our meteor network by setting up new stations that will allow to improve the quality of the results.

Table 5 – Orbital elements for 26 Geminids recorded during the night of their maximum December 13–14, 2013.

n	Sol	a	q	e	i	ω	Ω	α	δ	V_g	D_{SH} SonotaCo	D_{SH} Phaeton
1	261.737	1.218	0.145	0.881	21.36	325.19	261.74	113.73	31.82	32.99	0.030	0.030
2	261.766	1.199	0.151	0.874	22.25	324.67	261.77	113.94	32.50	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	34.00	0.021	0.031
7	261.877	1.301	0.154	0.882	22.50	323.16	261.88	112.91	32.67	33.38	0.012	0.046
8	261.879	1.322	0.146	0.890	23.28	324.06	261.88	113.33	32.49	33.96	0.013	0.038
9	261.884	1.260	0.147	0.883	21.93	324.43	261.88	113.48	32.11	33.29	0.016	0.030
10	261.891	1.422	0.139	0.902	24.29	324.19	261.89	113.16	32.40	34.99	0.035	0.049
11	261.893	1.235	0.149	0.880	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	33.00	0.034	0.033
14	261.935	1.231	0.154	0.875	22.18	323.89	261.94	113.59	32.59	32.80	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	261.950	1.364	0.146	0.893	22.71	323.69	261.95	112.90	32.24	34.19	0.010	0.037
18	261.978	1.331	0.140	0.895	22.72	324.76	261.98	113.50	31.93	34.22	0.021	0.026
19	261.989	1.376	0.143	0.896	23.06	324.02	261.99	113.10	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	1.320	0.148	0.888	22.72	323.80	262.01	113.25	32.37	33.80	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	22.10	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	22.50	324.81	262.17	114.29	32.29	33.12	0.020	0.025
mean		1.296	0.147	0.887	22.60	324.20	261.93	113.42	32.30	33.63	0.018	0.036
std.dev.		0.061	0.004	0.007	0.88	0.56	0.09	0.41	0.32	0.61	0.009	0.007

Table 6 – 20 Q3 quality orbits for the 2014 Perseids compared to the mean orbit by SonotaCo and the orbit of the parent comet 109P/Swift-Tuttle.

n	Sol	a	q	e	i	ω	Ω	α	δ	V_g	D_{SH} SonotaCo	D_{SH} Swift-Tuttle
1	137.923	11.472	0.955	0.917	113.61	151.60	137.92	44.26	56.97	58.96	0.037	0.082
2	138.028	15.884	0.964	0.939	113.00	154.02	138.03	43.02	57.39	59.03	0.049	0.043
3	139.000	8.382	0.956	0.886	111.53	151.49	139.00	45.15	58.34	58.00	0.056	0.093
4	139.008	14.852	0.963	0.935	115.77	153.68	139.01	45.01	56.01	59.86	0.069	0.060
5	139.008	20.861	0.964	0.954	113.41	154.26	139.01	44.39	57.49	59.31	0.064	0.022
6	139.050	20.392	0.960	0.953	114.47	153.05	139.05	45.37	56.92	59.62	0.052	0.036
7	139.103	9.572	0.956	0.900	115.74	151.69	139.10	45.98	55.95	59.48	0.060	0.089
8	139.800	14.328	0.957	0.933	114.78	152.37	139.80	46.69	56.86	59.52	0.049	0.047
9	139.828	14.585	0.958	0.934	113.97	152.51	139.83	46.52	57.35	59.28	0.044	0.037
10	139.868	11.050	0.968	0.912	112.45	155.13	139.87	44.50	58.03	58.62	0.088	0.062
11	139.961	30.561	0.960	0.969	112.47	153.31	139.96	46.27	58.45	59.15	0.069	0.012
12	139.968	32.765	0.959	0.971	110.80	153.01	139.97	46.23	59.48	58.62	0.076	0.038
13	140.020	20.468	0.952	0.953	113.20	151.18	140.02	47.70	58.01	59.20	0.031	0.034
14	140.058	24.112	0.960	0.960	113.90	153.11	140.06	46.69	57.58	59.52	0.064	0.018
15	140.059	10.134	0.952	0.906	113.41	150.79	140.06	47.54	57.65	58.80	0.031	0.069
16	140.886	8.015	0.953	0.881	113.29	150.82	140.89	48.39	57.79	58.52	0.061	0.087
17	140.911	13.992	0.956	0.932	114.07	151.97	140.91	48.35	57.58	59.29	0.055	0.041
18	140.961	22.483	0.949	0.958	113.66	150.49	140.96	49.56	58.03	59.39	0.042	0.036
19	141.075	16.370	0.944	0.942	114.04	149.32	141.08	50.34	57.77	59.34	0.029	0.057
20	142.867	12.708	0.947	0.926	113.33	149.82	142.87	52.32	58.54	58.98	0.066	0.062
mean		16.649	0.957	0.933	113.55	152.18	139.87	46.71	57.61	59.13	0.055	0.051
std.dev.		6.955	0.006	0.026	1.20	1.54	1.14	2.27	0.83	0.44	0.016	0.024

Finally the educational aspects of this work are also important. In activities of this network we include secondary school pupils or students of natural sciences who can conduct initial analysis allowing them to make a first experiences in serious scientific research.

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Nedim Mujić during his presentation (Photo by *Axel Haas*).