Central European MetEor NeTwork: Current Status and Future Activities

Jiří Srba[1,2], *Jakub Koukal*[1,2], *Martin Ferus*[3], *Libor Lenža*[1], *Sylvie Gorková*[1,2], *Svatopluk Civiš*[3], *Jaroslav Simon*[4], *Tibor Csorgei*[5], *Miroslav Jedlička*[2,6], *Matej Korec*[7], *Stanislav Kaniansky*[8], *Jiří Polák*[9], *Miroslav Spurný*[2,10], *Tomáš Brázdil*[11], *Ján Mäsiar*[12], *Martin Zima*[2], *Peter Delinčák, Martin Popek, Vladimír Bahýl, Roman Piffl, and Michal Čechmánek*

The Central European video Meteor Network (CEMeNt) established in 2010 is a platform for cross-border cooperation in the field of video meteor observations between Czech Republic and Slovakia. During five years of operation the CEMeNt network went through an extensive development. In total, 37 video systems were working on 20 permanent stations located in Czech Republic and Slovakia during 2015. In this paper we summarize CEMeNt current status and introduce some future activities.

Received 2016 May 5

1 Introduction

The Central European video Meteor Network (CEMeNt) was established in 2010 by Roman Piffl (Slovakia) and Jakub Koukal (Czech Republic, Society for Interplanetary Matter, SMPH, z. s.[a]) as a non-institutional platform for cross-border cooperation in the field of video meteor observations in central Europe. From the beginning the CEMeNt has been organized as a network of mostly amateur astronomers with low-cost, wide field video-systems for meteor activity monitoring. The CEMeNt observational activities have been coordinated with professional Slovak Video Meteor Network (SVMN, (Tóth et al., 2008)), as well as with other similar networks in the area of central Europe (especially Hungarian Meteor Network, HMN (Igaz, 2012) and Polish Fireball Network, PFN (Olech et al., 2006)). Acquired meteor data enables scientists to obtain high precision positions and velocity observations for multi-station meteor orbits calculations.

Video-systems used in CEMeNt are based on various types of sensitive CCTV video cameras with 1/3" or 1/2" chip and fast ($\sim f/1.0$) varifocal lenses. For detection and analysis, the UFOTools software pack by SonotaCo (SonotaCo, 2009) is used. Most of the stations are 'wide field' with a diagonal field of view about 60–90 degrees. Camera systems are sheltered in weatherproof and heated housings (generally used for security camera systems). In the area of central Europe these stations are able to work for the whole year, without climatic limitations. Some of the stations can also be operated on-line with necessary technical service only. A new type of specialized high sensitive camera system with narrow field of view was introduced in 2015. The system is called the NFC (Narrow Field Camera, (Koukal et al., 2015b)) and now six NFC stations are operating in the CEMeNt network. For more information, see chapter 'NFC project'.

All meteor data produced in the CEMeNt network are available in an open database EDMONd (Kornoš et al., 2014).

Since 2014, the research in CEMeNt is also oriented on spectral observations of bright meteors (Koukal et al., 2015a). Spectroscopic systems are using a classical wide field station design with diffraction grating added in front of the lens. Detailed information on the CEMeNt meteor spectroscopy project is in the chapter entitled 'Spectroscopic observations'.

Except for the video meteor observations, a radio experiment SMRST (Small Meteor Radio Scatter equipmenT) is operated in cooperation with SMPH at Vsetín Observatory. The main goal of these devices is to monitor meteor activity during daylight. In cases of bright bolides, it is possible to link radio detections with their video counterparts.

2 Stations introduction

In total, 37 video systems had been installed on 20 permanent stations located in Czech Republic and Slovakia in February 2016. In the following chapter, we would

[1]Valašské Meziříčí Observatory, Vsetínská 78, 757 01 Valašské Meziříčí, Czech Republic. Email: jsrba@astrovm.cz, j.koukal@post.cz, sgorkova@astrovm.cz

[2]SMPH, Society for Interplanetary Matter, public association, Kraví hora 522/2, 61 600 Brno, Czech Republic

[3]J. Heyrovský Institute of Physical Chemistry, Czech Academy of Sciences Dolejškova 3, CZ18223 Prague 8, Czech Republic. Email: martin.ferus@jh-inst.cas.cz, svatopluk.civis@jh-inst.cas.cz

[4]SOLAR Observatory Senec, public association, Dlhá 24/F, 903 01 Senec, Slovakia. Email: observatorium@solarastronomy.sk

[5]UMa Astronomy Association, Blahová 54, 930 52 Blahová, Slovakia. Email: info@observatory.sk

[6]Museum of the Moravian Wallachia Region, Vsetín Observatory, Jabloňová 231, 755 00 Vsetín, Czech Republic. Email: jedlicka@hvezdarna-vsetin.cz

[7]Maximilian Hell Observatory and Planetarium in Žiar nad Hronom, Dukelských hrdinov 21, 965 01 Žiar nad Hronom, Slovakia. Email: korec@planetarium.sk

[8]Maximilian Hell Observatory and Planetarium in Žiar nad Hronom, Banská Bystrica Observatory, Komenského 12, 975 90 BanskÃą Bystrica, Slovakia. Email: sky@planetarium.sk

[9]Observatory and Planetarium Plzeň, U Dráhy 306/11, 318 00 Plzeň, Czech Republic. Email: jiri.polak@centrum.cz

[10]František Krejčí Observatory in Carlsbad, K letišti 144, 360 01 Karlovy Vary, Czech Republic. Email: hvezdarna@astropatrola.cz

[11]Zlín Observatory ZAS, Lesní čtvrť III/5443, 760 01 Zlín, Czech Republic. Email: zas@zas.cz

[12]Regional Observatory in Žilina, Kysuce Observatory, Dolinský potok 1278, 024 01 Kysucké Nové Mesto, Slovakia. Email: kyshvezdknm@vuczilina.sk

IMO bibcode WGN-443-srba-cement
NASA-ADS bibcode 2016JIMO...44....1S

[a]http://www.kommet.cz/contact

like to introduce some stations with exceptional personal or institutional backgrounds. Stations are sorted alphabetically. In some cases, one observer/institution is operating more than one station. These are only mentioned briefly in the main text. The full station summary is in Table 1.

Banská Bystrica Observatory

The *Banská Bystrica Observatory*[b] is a subsidiary of *Maximilian Hell Observatory and Planetarium in Žiar nad Hronom* (Banská Bystrica Region, Slovakia). The observatory is located on the Vartovka Hill, near the town of Banská Bystrica, where the video meteor station **Vartovka** is also installed. In its scientific work, the observatory is focused on interplanetary matter research. Video-meteor observations, cooperated with CEMeNt, started in August 2012. Station operation and data processing is supported by observatory staff.

František Krejčí Observatory in Carlsbad

Stations **Karlovy Vary**, **Ostrov**, **Toužim** and **Sokolov** (all in Karlovy Vary Region, Czech Republic) are operated from *František Krejčí Observatory in Carlsbad* by observatory staff. These stations were installed in 2015 as a part of educational project realized in cooperation with SMPH.

Kroměříž

Kroměříž is privately funded station located at a loggia of an apartment house on the outskirts of the town Kroměříž (Zlín Region, Czech Republic). The station is equipped with two wide field cameras. The southeastern camera has been in operation since October 2011, the northeastern one from January 2012. The other CEMeNt station – Maruška – is also operated from Kroměříž. In April 2015 the first camera of the NFC system was also installed in Kroměříž (see chapter 'NFC project'). All of these camera systems' operation and data processing is supported by owner Jakub Koukal.

Maruška

Video meteor station **Maruška**[c] is located at a climatological station of the *Czech Hydro Meteorological Institute*[d] (CHMU) on the Maruška Hill in Hostýn Mountiens (Zlín Region, Hošťálková, Czech Republic). This station is equipped with two wide field cameras. The first camera has been in operation since June 2012. The second camera was installed in October 2012. These stations were realized in cooperation with SMPH.

Kysuce Observatory

The station in Kysucké Nové Mesto (Žilina Region, Slovakia) has a special importance among the CEMeNt stations. It is operated by *Kysuce Observatory* (headquarters of the *Regional Observatory in Žilina*, organization funded by Žilina Region local government). On the roof of the Kysuce observatory main building, an all sky camera system AMOS (Zigo et al., 2013) is installed. It was developed by *Astronomical and Geophysical Observatory* of the *Komenius University in Bratislava* for professional network SVMN. This station was installed in 2011 during parallel cross-border experiments with *Valašské Meziříčí Observatory*, within the framework of the educational/scientific project KOSOAP[e]. Data from this camera are also part of the SVMN archive and so the Kysucké Nové Mesto station plays a key role in CEMeNt /SVMN cooperation.

In 2015 the third station of the NFC system was installed in Kysucké Nové Mesto (see chapter 'NFC project'). The NFC system operation and data processing is supported by observatory staff.

Nýdek

The Nýdek (Nýdek Gora, Moravian-Silesian Region, Czech Republic) is a private founded station, one of the longest operational stations of the CEMeNt network with first meteor observation from April 2010. Since May 2011 the station is primary intended for TLE (Transient Luminous Events, (Mlynarczyk et al., 2015)) observations, but meteor cameras are still operational and useful for covering the northern part of the CEMeNt network. Station operation and data processing is supported by owner, Martin Popek.

Otrokovice

Station **Otrokovice** is in operation since 2015 and is equipped with one meteor camera. The system is located in the backyard of a family house in the town of Otrokovice (Zlín Region, Czech Republic). The system covers the same field of view as spectroscopic cameras in Valašské Meziříčí. Operation and data processing is supported by the owner, Michael Čechmánek.

Plzeň

The video-meteor station in Plzeň (Southern Bohemia Region, Czech Republic) is operated by **Observatory and Planetarium Plzeň** (contributory organization funded by town Plzeň). The station was installed in October 2012, with a field of view enabling meteor pairing with stations operated by **František Krejčí Observatory in Carlsbad** and with a private station in Stochov. Operation and data processing is supported by Jiří Polák and observatory staff.

SOLAR Senec Observatory

The video-meteor station in **Senec** is operated by the public astronomical association *SOLAR Senec Observatory* (*SOLAR Hvezdáreň Senec*[f]). Since 2006 the association operates an astronomical observatory on the roof of the *A. Molnar Szenczihо Hungarian language elementary school in Senec*[g]). The observatory is located in the center of town Senec (Bratislava Region, Slovakia). In January 2015 SOLAR association joined the CEMeNt network when two CCTV camera sys-

[b] http://www.astrobb.sk
[c] http://maruska.ordoz.com
[d] http://portal.chmi.cz
[e] www.astrovm.cz/cz/program/projekty/realizovane-projekty/kosoap.html, in Czech
[f] http://www.solarastronomy.sk
[g] http://zsamszenczihо.edupage.sk

Table 1 – CEMeNt 2015 detail station list. Used abbreviations: Loc. – location (state), Alt. – altitude, Dia. – field of view diameter, Az. and Ele. – azimuth and elevation of the field of view center; camera type abbr.: SC – standard wide field camera, SP – spectrograph, NFC – Narrow Field Camera.

Station, state	Approx. coordinates. (N, E, Alt.)	Field of view Code (Dia., Az., Ele.)	Type	Operator/ Observer	Institution/ Association
Vartovka, SR	48 °.718, 19 °.155, 568 m	N (62 °.0, 30 °.7, 53 °.7)	SC	S. Kanianský	Banská Bystrica Obs.
Karlovy Vary, CR	50 °.216, 12 °.906, 615 m	N (73 °.3, 359 °.5, 51 °.2) S (64 °.1, 197 °.8, 45 °.1)	SC	S. Gorková	Karlovy Vary Obs.
Ostrov, CR	50 °.303, 12 °.953, 400 m	S (36 °.0, 152 °.4, 20 °.0)	SC	J. Koukal	Karlovy Vary Obs.
Otrokovice, CR	49 °.211, 17 °.531, 205 m	N (78 °.4, 2 °.2, 45 °.2)	SC	M. Čechmánek J. Koukal	
Blahová, SR	48 °.085, 17 °.547, 124 m	01 (57 °.0, 83 °.5, 29 °.1) 02 (85 °.0, 151 °.2, 49 °.3) 03 (74 °.2, 305 °.0, 38 °.4) 04 (87 °.2, 240 °.5, 44 °.2) NFC (6 °.8, 6 °.3, 38 °.4)	SC SC SC SC NFC	T. Csorgei	UMa Astronomy
Kostolné Kračany, SR	47 °.985, 17 °.567, 120 m	05 (83 °.5, 12 °.1, 45 °.6)	SC	T. Csorgei K. Molnar	UMa Astronomy
Kroměříž, CR	49 °.290, 17 °.383, 222 m	ENE (76 °.3, 52 °.8, 41 °.6) SE (74 °.9, 115 °.0, 43 °.6) NFC (6 °.8, 28 °.3, 43 °.4)	SC SC NFC	J. Koukal	
Kysucké Nové Mesto, SR	49 °.307, 18 °.765, 417 m	NFC (6 °.8, 0 °.0, 45 °.3)	NFC	S. Gorková	Kysucké N. Mesto Obs.
Lovčica, SR	48 °.683, 19 °.858, 696 m	SW (91 °.1, 216 °.4, 59 °.8)	SC	M. Korec	
Maruška, CR	49 °.366, 17 °.828, 656 m	SE (79 °.6, 148 °.2, 43 °.1) SW (79 °.0, 231 °.9, 46 °.0)	SC SC	J. Koukal	SMPH
Nýdek, CR	49 °.668, 18 °.769, 475 m	W (42 °.1, 262 °.2, 18 °.0) SW (34 °.3, 223 °.5, 16 °.3) NW (40 °.7, 304 °.2, 21 °.3)	SC SC SC	M. Popek	
Plzeň, CR	49 °.744, 13 °.349, 335 m	NW (75 °.8, 331 °.0, 44 °.7)	SC	J. Polák	Plzeň Observatory
Senec, SR	48 °.220, 17 °.395, 128 m	W (57 °.2, 296 °.9, 42 °.9) E (57 °.3, 62 °.4, 46 °.8) N (57 °.1, 359 °.1, 44 °.3) NFC (6 °.8, 11 °.8, 42 °.0)	SC SC SC NFC	J. Simon	Solar Observatory Senec
Sokolov, CR	50 °.176, 12 °.640, 425 m	NE (35 °.9, 53 °.9, 18 °.7)	SC	J. Koukal	Karlovy Vary Obs.
Toužim, CR	50 °.057, 12 °.991, 625 m	S (44 °.9, 161 °.4, 14 °.9)	SC	J. Koukal	Karlovy Vary Obs.
Valašské Meziříčí, CR	49 °.463, 17 °.974, 337 m	E (79 °.4, 94 °.1, 45 °.6) S (84 °.4, 176 °.1, 48 °.6) NFC (6 °.9, 4 °.0, 53 °.8) SW (81 °.0, 227 °.3, 48 °.3) NW (90 °.1, 286 °.5, 51 °.1) N (66 °.6, 348 °.2, 41 °.7)	SC SC NFC SP SP SP	J. Srba J. Koukal S. Gorková	Valašské Meziříčí Obs. SMPH
Vsetín, CR	49 °.661, 17 °.996, 389 m	E (78 °.2, 93 °.8, 47 °.6)	SC	M. Jedlička	Vsetín Observatory
Zlín, CR	49 °.218, 17 °.692, 349 m	N (70 °.3, 359 °.6, 49 °.1)	SC	J. Koukal	Zlín Observatory
Zákopčie, SR	18 °.703, 49 °.404, 682 m	NFC (6 °.9, 2 °.7, 50 °.4)	NFC	P. Delinčák	
Zvolenská Slatina, SR	48 °.565, 19 °.256, 320 m	S (72 °.9, 182 °.5, 39 °.8)	SC	V. Bahýl	Observatory Júlia

tems were installed. The third wide field system (facing north) has been in operation since December 2015. Operation and data processing is supported by association member Jaroslav Simon. Since October 2015 the association is also involved in realization of the NFC project with one installed camera (see 'NFC project').

Stochov

A privately funded station in Stochov was installed in 2010 as one of the first CEMeNt stations. It is located in the western part of the Czech Republic in town Stochov (Central Bohemia Region, Czech Republic), in a region without CEMeNt Slovakia segment border. Station operation and data processing is supported by owner Martin Zima. This station is coordinating observations with *František Krejčí Observatory in Carlsbad* and *Observatory and Planetarium Plzeň*.

Valašské Meziříčí Observatory

The *Valašské Meziříčí*[h] is a contributory organization founded by Zlín Region local government. Experimental video-meteor observations in Valašské Meziříčí (Zlín Region, Czech Republic) started in 2011 within the frame of the cross-border educational/research project KOSOAP realized in cooperation with Slovak partner, *Kysuce Observatory*.

During the KOSOAP project, one station for video meteor observations was tested and operated in cooperation with CEMeNt. Based on the project results, two fixed wide field camera systems were installed in November 2012. Cameras are covering the eastern and southern sky for effective cooperation with the parallel build Slovak segment.

[h] `http://www.astrovm.cz`

Since 2014, the *Valašské Meziříčí* is also involved in other CEMeNt activities (NFC project and meteor spectroscopy; see appropriate chapters). Station operation and data processing is supported by observatory staff.

Vsetín Observatory

Vsetín Observatory[i] is a subsidiary of the *Museum of the Moravian Wallachia Region* funded by Zlín Region local government. The observatory joined CEMeNt network in February 2013, station is located in the northern part of the town Vsetín (Zlín Region, Czech Republic). Operation and data processing is supported by Miroslav Jedlička and observatory staff.

Since 2009 the Vsetín Observatory is also operating the SMRST[j] experiment (Small Meteor Radio Scatter equipmenT) for radio meteor detection.

UMa Astronomy Association

Civil astronomical association *UMa Astronomy* operates two stations for video meteor observations. In Blahová (Dunajská Streda, Slovakia) there are actually four wide field systems installed. The first camera is in operation since November 2014, others were installed during 2015. The fifth camera operated by the association members was installed in August 2015 at new location in village **Kostolné Kračany** (Dunajská Streda, Slovakia). *Uma Astronomy association* is also involved in the NFC project realization (see chapter 'NFC project'). All systems are operated and data reduced by Tibor Csörgei and K. Molnár. UMa Astronomy video meteor database and web presentation[k] is maintained by Libor Pálinkás.

Zákopčie

Station **Zakopčie** is situated on a hill above the village Zakopčie in the northwest Slovakia, near town Čadca (Žilina Region, Slovak Republic). Meteor observations are actually devoted to the NFC project. The NFC station is located next to a small private observatory primarily focused on asteroid occultation observations and astronomical photography. Station operation and data processing for further analyses is supported by observatory owner Peter Delinčák. The observatory has its own web site[l].

Zlín Observatory

This station is located on the building of *Zlín Observatory*[m] (Zlín, Zlín Region, Czech Republic). The whole observatory is operated and funded by Zlín astronomical society (ZAS) in a building owned by town Zlín. The video meteor station was installed in June 2014 with a field of view oriented to the north (azimuth 0 deg). This orientation is important for meteor pairing and orbit calculations in cooperation with station Otrokovice and spectroscopic stations in Valašské Meziříčí. Operation and data processing is supported by members of the astronomical society.

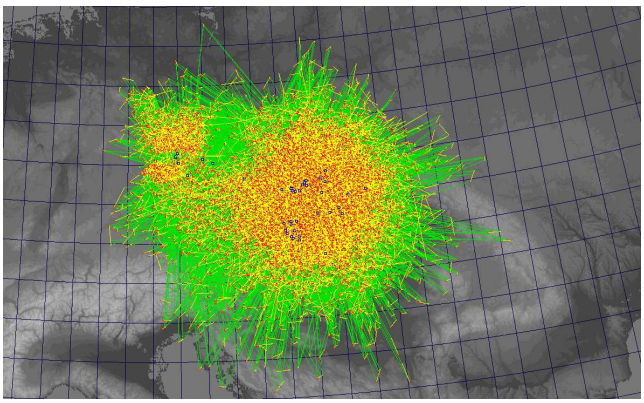

Figure 1 – Ground map (central Europe) of all multi-station meteors registered by CEMeNt stations from 2010 to 2015. Overall stations positions are marked (blue circles).

Zvolenská Slatina

Video-meteor observation at private Observatory Júlia started on August 2012 within the frame of the Bright Bolide Watch program running from May 2011. The station is located in the **Zvolenská Slatina** village, near town Zvolen (Banská Bystrica, Slovakia). The Observatory Júlia and its video-meteor station is fully privately funded and operated by owner Vladimir Bahyl. Data processing is supported in cooperation with CEMeNt co-founder Roman Piffl.

3 CEMeNt 2010–2015 short results overview

Since the CEMeNt network has now been operating for five years in a row, we would like to present here some short network observational statistics. During the period 2010 to 2015, in total, 147 368 individual meteors were registered, 26 207 of them were observed from more than one station, so it was possible to calculate their atmospheric trajectory and orbit. Figure 1 shows a ground map of central Europe with more than 26 thousand CEMeNt registered multi-station meteors.

The Figure 2 shows the radiant data for these meteors, along with color-coded velocity information. Some of the most prominent meteor showers are visible as radiant concentrations of meteors with same geocentric velocity.

The complete year/station statistics for CEMeNt network is shown in Table 2.

4 NFC project

In 2014 a new type of narrow field, highly sensitive camera system was introduced in CEMeNt. The system is called NFC (Narrow Field Camera) (Koukal et al., 2015b) and its main component is a fast 50 mm prime lens Meostigmat 1/50 (produced in CR by *Meopta*[n] since 1960, dedicated for 16 mm film projection). The

[i] http://www.hvezdarna-vsetin.cz
[j] http://www.hvezdarna-vsetin.cz/showpage.php?name=smrst_data
[k] http://observatory.sk/videometeor.php
[l] http://www.astronomy.sk
[m] http://www.zas.cz
[n] http://www.meoptahistory.com/index.php?id=131

Table 2 – CEMeNt 2009–2015 wide field stations and observation statistics.

	Station location	2009	2010	2011	2012	2013	2014	2015	Total
Stations in operation	Vartovka				1 264	2 192	1 342	1 810	6 608
	Karlovy Vary				691	3 793	2 839	4 066	11 389
	Ostrov							152	152
	Otrokovice					842	893	2 134	3 869
	Blahová						364	7 561	7 925
	Kostolné Kračany							981	981
	Kroměříž		2 067	3 182	5 964	4 467	3 363	4 370	23 413
	Lovčica			73	151	596	336	609	1 765
	Maruška				4 292	5 730	4 742	4 552	19 316
	Nýdek		1 909	1 126	180	2 369	3 539	7 424	16 547
	Plzeň				837	1 854	1 499	1 186	5 376
	Senec							2 791	2 791
	Sokolov							32	32
	Toužim							356	356
	Valašské Meziříčí			520	1 799	6 051	5 713	8 007	22 090
	Vsetín					1 257	1 033	1 110	3 400
	Zlín						743	1 526	2 269
	Zákopčie				431				431
	Zvolenská Slatina				515	478	605	1 765	3 363
	Mobile st. (total)		805	432	739	70	119	355	2 520
Inactive stations	Bratislava	660							660
	Dunajská Lužná		153	318	1 017	432			1 920
	Mariánka		777	258					1 035
	Stochov		442	433	1 424	133			2 432
	Bílý Kříž				1 439	2 177	142		3 758
	Havlíčkův Brod				451	925	609		1 985
	Barrandov					1 474	1 016		2 490

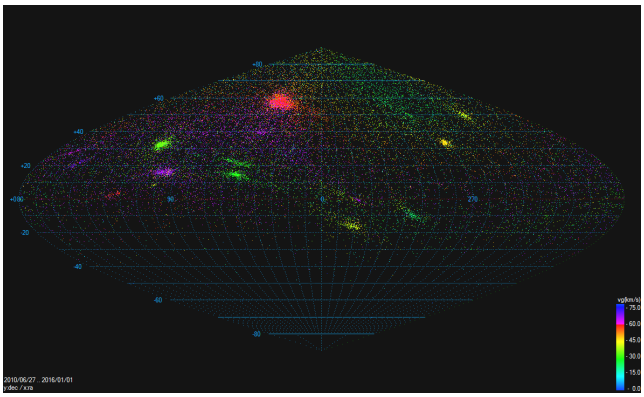

Figure 2 – Radiants of all multi-station meteors registered by CEMeNt stations from 2010 to 2015.

Watec 902H2 Ultimate CCD camera (with 1/2" chip) is used and the combination with the 50 mm prime lens results in the system narrow field of view about 10° on diagonal. The NFC camera system is able to capture meteors down to magnitude 7. At present, 6 stations equipped by the NFC are working in CEMeNt network.

Because of the narrow field of view, standard pairing of meteor observations with wide field stations is highly improbable. Since orbit calculations for meteors captured by NFC cameras has been required, the NFC network stations are organized in stable pairs. Alt./Az. orientation of cameras in each pair is set to be covering the same space in the atmosphere (at altitude 100 km). Cameras in one pair are registering the same meteors, so orbits can be calculated. Because of the lens limitations (full open construction without iris) NFC cameras are only covering an area around the northern celestial pole to avoid direct frontal solar illumination during the day.

The first two pairs of the NFC system were installed in April and May 2015 respectively. This part of the NFC network was build within the frame of the cross-border educational/research project RPKS[o] (*Evolvement of the Cross Border Network for Scientific Work and Education*) realized by Valašské Meziříčí Observatory and Regional Observatory in Žilina as KOSOAP follow-up project. The first NFC pair is operated at stations Kroměříž and Valašské Meziříčí. The second pair was installed in Slovakia at Kysucké Nové Mesto and Zákopčie.

The third NFC pair in CEMeNt was installed in October 2015, also in Slovakia. One camera is located at the observatory operated by astronomical association *SOLAR Senec Observatory* in Senec. The second is operated by *Uma Astronomy association* in Blahová.

During 2015, all six working stations of the NFC system registered together 4 324 individual meteors. The complete observation statistics of the NFC project (since the first experiments in 2014 to the end of 2015) is shown in Table 3.

[o] `http://www.astrovm.cz/cz/program/projekty/realizovane-projekty/rozvoj-preshranicni-kooperujici-site-pro-odbornou-praci-a-vzdelavani.html`, in Czech

Table 3 – NFC 2014–2015 stations and observation statistics.

NFC Station	2014	2015	Total
Kroměříž	29	1 306	1 335
Valašské Meziříčí	25	987	1 012
Senec	—	321	321
Blahová	—	403	403
Zákopčie	—	726	726
Kysucké Nové Mesto	—	581	581
Total	54	4 324	4 378
Orbits	14	919	933

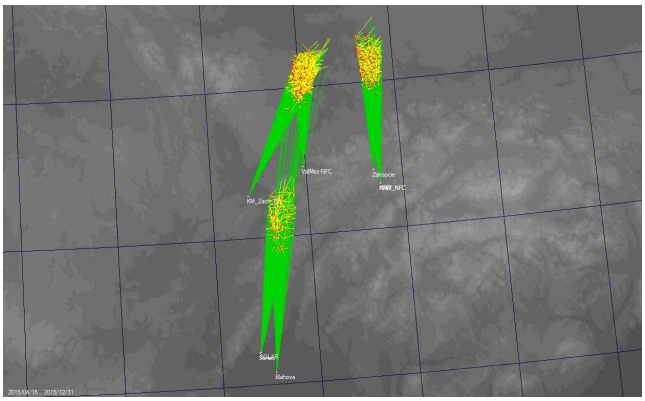

Figure 3 – Ground map of the NFC stations meteor pairings in 2015. Few three-station meteors from an experimental run of the NFC at Senec are visible (observation from Senec was for few weeks covering same atmospheric space as stable NFC pair Kroměříž-Valašské Meziříčí).

For 933 paired meteors it was possible to calculate very accurate trajectories in the atmosphere and the meteoroids' orbits in the solar system. A ground map (projection of the meteor atmospheric trajectory on the ground) for these paired meteors is shown on Figure 3.

5 Meteor spectroscopy

The first spectroscopic observations in the CEMeNt network were regularly performed by Jakub Koukal on an experimental setup from Kroměříž. Based on these experiments, two types of spectroscopic wide field systems are actually used in CEMeNt network.

The old system uses classic wide field CCTV station design only with diffraction grating (500 lines/mm) added in front of the lens. A still experimental new generation spectroscopic system uses higher resolution USB CMOS camera QHY 5L-II-M (Korec, 2015) (no TV-PAL output/input conversion, 1/3" chip with resolution 1920 × 1200). In front of the megapixel Tamron CCTV lens (M13VG308, (Korec, 2015) an Edmund Optics[p] 1000 lines/mm diffraction grating is placed. SonotaCo's UFO detection software in HD version is used experimentally in these spectroscopic systems. Theoretical spectral resolution is around 1 nm/pixel. Video data from both types of spectroscopic systems are also used for orbit calculations (together with other classic CEMeNt stations), so that we can obtain an accurate orbit of the meteoroid and basic spectral characteristic of its material.

[p] http://www.edmundoptics.com

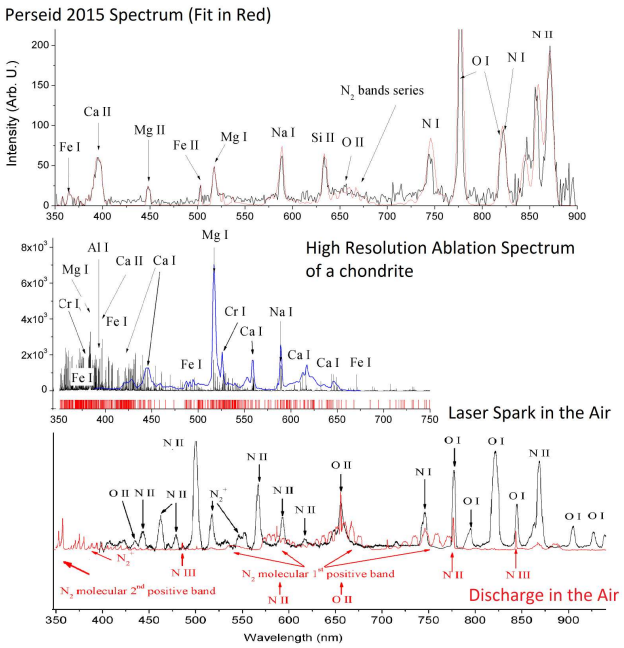

Figure 4 – Comparative spectra of a real meteor (one of the Perseid Meteor Shower 2015 – marked in black), spectra simulation (marked in red) together with high resolution laser plasma spectrum of chondrite Dhofar 1709 simultaneously measured using meteor spectrograph (in blue) and laser spark and discharge plasma in atmospheric gases.

Our goal is to collect large sample of CCTV/CCD meteor spectra for physical/chemical characteristics of incoming material, together with high quality orbits suitable for EDMOND database.

Since 2015, CEMeNt is cooperating on spectroscopic experiments with *J. Heyrovsky Institute of Physical Chemistry* (institute of the Czech Academy of Sciences) and Valašské Meziříčí Observatory. Our research project *Meteor Observation and Spectroscopy Infrastructure Evolvement*[q] has been funded by the programme of Regional cooperation of the Czech Academy of Sciences, grant no. R200401521. In order to better understand the chemistry and spectroscopy of meteor plasma, we implemented calibration free data processing in emission data evaluation and comparative algorithms for an analysis of reference spectra acquired in laboratory experiments involving Laser Induced Breakdown Spectroscopy of Meteorite samples, Laser Induced Sparks in atmospheric gases and electric discharges, together with in-situ simultaneous measurement by meteor spectrograph and high resolution echelle instrument. The results have been compared with real meteors spectra obtained from CEMeNt. All of the measurements are realized with professional laboratory equipment at J. Heyrovsky institute (Ferus et al., 2015). The example of spectral comparison is shown in Figure 4.

6 Future activities

For 2016 and the following years, we plan to expand the Slovak segment of the CEMeNt network to the mid and

[q] in Czech: Rozvoj pozorování a spektroskopie meteorů a meteoritů

eastern part of Slovakia to improve cooperation with the HMN (Hungarian Meteor Network, Magyar Hullócsillagok Egyesulet) and the MeteorsUA (Ukraine network). There are three new stations already scheduled for installation in 2016 – Rimavská Sobota Observatory (Hvezdáreň Rimavská Sobota), Roztoky Observatory (Hvezdáreň Roztoky) and Astronomical Observatory Kolonica at Kolonica saddle.

Expansion of the CEMeNt Czech segment is also planned. Some new stations are to be installed in 2016 in the central, western and northern parts of the Czech Republic – stations: Malá Skála, Aš, Žebrák Observatory and Soběslav-Svákov.

At Valašské Meziříčí Observatory two new spectroscopic cameras NE (north-east) and SE (south-east) are planned for installation to fully cover the whole sky for meteor spectra research. Other spectroscopic cameras with high resolution are to be installed by Uma Astronomy association.

In cooperation with SVMN, we plan to install wide field and spectral cameras along with the professional all sky cameras operated by SWMN at Canary Islands.

Acknowledgement

We would like to thank to all station owners, operators and observers for long term and precise work enabling CEMeNt network independent operation. Also we would like to thank to all institutions involved for still growing support of network activities.

Projects KOSOAP (Cooperating Network of Astronomic Observational Projects, in Czech: Kooperující síť v oblasti astronomických odborně-pozorovatelských programů) and RPKS (Evolvement of the Cross Border Network for Scientific Work and Education, in Czech: Rozvoj přeshraniční kooperující sítě pro odbornou práci a vzdělávání) realized by Valašské Meziříčí Observatory (CZ) and Kysuce Observatory (SK) in cooperation with Society for Interplanetary Matter (SMPH) were co-funded by European Union (Cross-border Cooperation programme Slovak Republic – Czech Republic 2007-2013).

References

Ferus M., Civiš S., Chatzitheodoridis E., Kubelík P., Knížek A., Svoboda V., Lenža L., Gorková S., and Koukal J. (2015). "Spectroscopy of meteors and meteorites ablation plasma". In *The 24th Colloquium on High Resolution Molecular Spectroscopy (HRMS 2015), Dijon, France*. (Poster).

Igaz A. (2012). "Development of the camera network in Hungary". In Gyssens M. and Roggemans P., editors, *Proceedings of the International Meteor Conference, Sibiu, Romania, 15-18 September 2011*. IMO, pages 100–101.

Korec M. (2015). "QHY (5L-II-M) CCD camera for video meteor observation". In Rault J.-L. and Roggemans P., editors, *Proceedings of the International Meteor Conference Mistelbach, Austria, 27-30 August 2015*. IMO, pages 85–89.

Kornoš L., Koukal J., Piffl R., and Tóth J. (2014). "EDMOND Meteor Database". In Gyssens M., Roggemans P., and Zoladek P., editors, *Proceedings of the International Meteor Conference, Poznań, Poland, 22-25 August 2013*. IMO, pages 23–25.

Koukal J., Gorková S., Srba J., Ferus M., Civiš S., and di Pietro C. A. (2015a). "Meteor spectra in the EDMOND database". In Rault J.-L. and Roggemans P., editors, *Proceedings of the International Meteor Conference Mistelbach, Austria, 27-30 August 2015*. IMO, pages 149–154.

Koukal J., Srba J., and Gorková S. (2015b). "NFC - Narrow Field Camera". In Rault J.-L. and Roggemans P., editors, *Proceedings of the International Meteor Conference Mistelbach, Austria, 27-30 August 2015*. IMO, pages 90–93.

Mlynarczyk J., Bór J., Kulak A., Popek M., and Kubisz J. (2015). "An unusual sequence of sprites followed by a secondary TLE: An analysis of ELF radio measurements and optical observations". *Journal of Geophysical Research*, **120:3**, 2241–2254.

Olech A., Żoładek P., Wiśniewski M., Krasnowski M., Kwinta M., Fajfer T., Fietkiewicz K., Dorosz D., Kowalski L., Olejnik J., Mularczyk K., and Złoczewski K. (2006). "Polish Fireball Network". In Bastiaens L., Verbert J., Wislez J.-M., and Verbeeck C., editors, *Proceedings of the International Meteor Conference, Oostmalle, Belgium, 15-18 September 2005*. IMO, pages 53–62.

SonotaCo (2009). "A meteor shower catalog based on video observations in 2007-2008". *WGN, Journal of the International Meteor Organization*, **37:2**, 55–62. (Actual info on the web: www.sonotaco.com).

Tóth J., Kornoš L., Gajdoš Š., Kalmančok D., Zigo P., Világi J., and Hajduková M. (2008). "TV Meteor Observations from Modra". *Earth Moon and Planets*, **102**, 257–261.

Zigo P., Tóth J., and Kalmančok D. (2013). "All-Sky Meteor Orbit System (AMOS)". In Gyssens M. and Roggemans P., editors, *Proceedings of the International Meteor Conference, La Palma, Canary Islands, Spain, 20-23 September 2012*. IMO, pages 18–20.

Handling Editor: Javor Kac