Croatian Meteor Network: ongoing work 2014 – 2015

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Ongoing work mainly between 2014–2015 International Meteor Conferences (IMC) has been presented. Current sky coverage, software updates, orbit catalogues updates, shower search updates, international collaboration as well as new fields of research and educational efforts made by the Croatian Meteor Network are described.

1 Introduction

In this paper we present ongoing work in the Croatian Meteor Network (CMN) between the IMC 2014–2015, as well as the achievements resulting from previous years' analysis. Topics covered by this paper contain information on current sky coverage of CMN cameras, improvements done on CMN software, status of CMN orbit catalogues, some results of CMN search for possible new meteor showers, results from international collaborations, a brief overview of new fields of research and efforts made on educating young people interested in meteor astronomy.

2 CMN coverage

During previous two years, the critical point in CMN funding has been reached which did not allow us to keep all of our video meteor stations active. This lack of funding resulted in lower number of cameras contributing to CMN observations (mainly in the southern part of Croatia), reducing the number of active cameras to 21. The sky coverage at 100km height can be seen in *Figure 1*.

Figure 1 – Sky coverage at height of 100 km.

As it can be seen, the whole sky over Croatia is well covered at the height of 100km, which means that the number of meteors detected by two or more stations should not be heavily affected, at least not for bright meteors. However, the number of fainter meteors captured by more than one station will be reduced, and we expect this will be confirmed once the orbit catalogues for 2014 and 2015 are done.

Figure 2 – Sky coverage at height of 20 km.

One of CMN goals is to monitor the sky for fireballs which could result in a meteorite fall. As noted in the case of the Križevci meteorite (Šegon, 2011), in order to have at least an estimation of the dynamical data at the fireball's terminal point the network should cover the sky volume as low as possible. Our current camera setup covers the sky over the northern part of Croatia very well down to the height of 20 km, as it can be seen in *Figure 2*. One of the things to do in the future is to recover video meteor stations in the southern parts of Croatia, which would allow us to have data on very low terminal height meteors as well as an increased number of fainter meteors captured by at least two stations, resulting in a higher number of meteoroid orbits.

3 CMN software updates

Besides capture/detection and orbit calculations, the Croatian Meteor Network uses its own software solutions for data management and processing. One of the main advances in data management has been done by introducing the ADAPT software (Vida, 2014), which allows us to have the data processed and ready for orbit determination – at the moment UFOOrbit (SonotaCo, 2009) software is used for this purpose. After more than a year running, it proved to be a very reliable and robust solution for our needs. Regarding capture software, 9 stations are running on single CAMS software at the resolution of 768x576 @25FPS, while the rest use SkyPatrol at resolutions of 720x576 or 384x288 due to PC hardware limitations. Once done, the resulting data are being uploaded to the CMN server, ready for orbit determination.

CMN_BinViewer is an application built for viewing single CAMS observations while providing additional possibilities and an alternative way to go through CAMS FF*.bin files. It has been tested and used by CAMS users not only in Croatia but in other parts of the world as well, having very positive feedback once the Confirmation part of the CAMS processing has been added. The current version allows SkyPatrol files to be viewed too.

One of the tools CMN has been developing is the "Shower Atlas", which is still in a testing phase. This web based application allows the user to go through radiant plots from the CMN and SonotaCo catalogues by a single degree of solar longitude and check for meteor grouping according to RA, Dec and velocity, as well as visualizing shower positions and dispersion according to the CMN shower search results. Once completed, the application will be publically available.

4 CMN orbit catalogues updates

From the very beginning of the Croatian Meteor network, the detection part has been the bottleneck in the data workflow. All observations recorded using SkyPatrol software were processed afterwards with MTP_Detector software, written by Peter Gural (Gural, 2009), in order to obtain meteor positional data as well as star positions needed for astrometry. Main issue was the fact that computers running the capture weren't able to do the processing during the daytime, so all observations were sent for processing on DVDs. This caused a significant delay of a few years to get from observations to the completed catalogue, so at the moment only the 2007–2012 catalogues were published.

A huge step ahead has been made once the ADAPT software has been deployed to almost all CMN stations, leaving only one standalone station. This means that we have all data ready to do final processing (astrometry) and we expect the catalogues for 2013–2014 will be published during 2015, while the catalogue for 2015 should be done during the first quarter of 2016.

5 CMN shower search updates

The first possible new shower detected by the Croatian Meteor Network was 444 ζ Cassiopeiids back in 2012 (Šegon, 2012). Since that discovery, which has been reported by the Polish Meteor Network as well (Zoladek, 2012), members of the CMN reported more than 100 possible new meteor showers. The main search for new meteor showers has been done during the spring of 2013, and new findings were published at the IMC 2013 (Šegon, 2014a) and Meteoroids 2013 (Šegon, 2014b) conferences in Poznan, Poland.

Before the International Astronomical Union (IAU) XXIX General Assembly which took place during August of 2015, twenty possible new meteor showers found by the CMN search were proposed to be established. Eight of them were accepted to be established during the meeting of IAU Commission 22. Established showers as from the official IAU MDC site[1] are: *June ρ Cygnids* (510 JRC), *ρ Puppids* (512 RPU), *λ Ursae Majorids* (524 LUM), *Southern λ Draconids* (526 SLD), *η Hydrids* (529 EHY), *July χ Arietids* (533 JXA), *49 Andromedids* (549 FAN) and *ο Hydrids* (569 OHY).

We find the fact that the IAU established these showers only a few years after they were initially reported very encouraging regarding our shower search method. There are also several papers about shower searches on other databases (Kornoš, 2014; Rudawska, 2014) from which quite a high number of newly reported showers by the CMN have also been found. We hope that the number of established showers from our search will increase at the next IAU meeting three years from now.

Meteoroid orbital databases are growing every year, making their analysis a more demanding task. In order to provide tools for amateur astronomers to do such analysis, we intend to publish open-source procedures written in Python.

6 International collaboration and results

Meteorite Križevci

More than four years after the fall of the Križevci meteorite, the paper on this event has been published (Borovička, 2015). An international team of scientists and amateur astronomers led by dr. Jiři Borovička did a complete analysis of the trajectory, dark flight and orbit determination of the H6 meteorite. We find two sentences from this paper to be very important for amateur astronomers: *"Križevci can be ranked among the 10 best documented falls."* meaning that observations coming from amateur video meteor networks may fit to high scientific standards, and *"Križevci became the first meteorite recovered on the basis of an amateur meteor network."* which should be a motivation for other networks to persist in their work. If we were lucky

[1] http://www.astro.amu.edu.pl/~jopek/MDC2007/Roje/roje_lista.php?corobic_roje=0&sort_roje=0

enough in finding a meteorite, other amateur networks will be as well – sooner or later.

Very important collaboration has been established with dr. Ian Lyon from the University of Manchester, UK, which did the analysis of the meteorite itself. Besides oxygen isotopes ratio determination, complete 3D X-ray tomography (example in *Figure 3*) has been done. The results show more than 165000 metal grains larger than 30µm as well as 6 pieces larger than 5mm. This work has been presented at 77th Annual Meteoritical Society Meeting 2014 (Lyon, 2014).

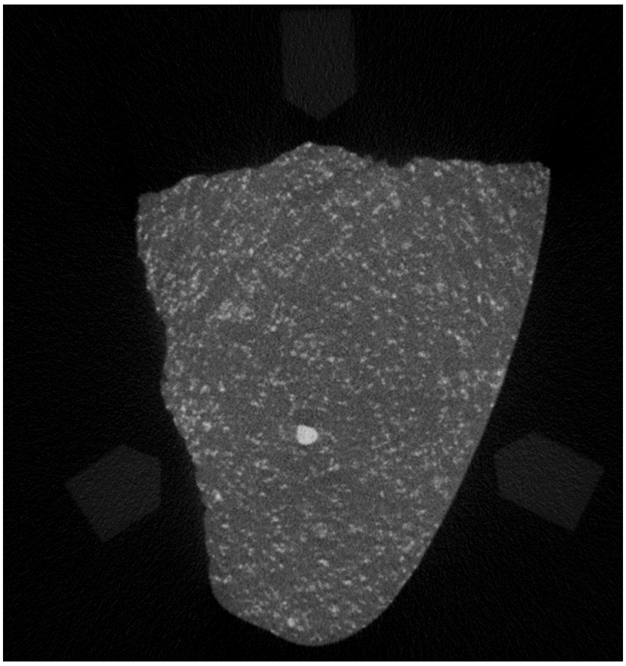

Figure 3 – 3D tomography slice, meteorite Križevci.

Showers and parent bodies

There were many critics regarding our matching of (possible new) meteor showers and their possible parent bodies. One very important thing that we would like to emphasize is that in all our papers on this topic we stated that such connections should be checked via dynamical modeling of hypothetical meteor showers produced by a parent body, and our findings only as a possibility until such dynamical models would confirm or deny such associations.

Thanks to Jeremie Vaubaillon, we had the possibility to check possible shower to parent body associations and the results are very exciting. Vaubaillon did a complete analysis using the same model (Vaubaillon, 2005) used for other predictions of the kind (Vaubaillon, 2011) on all parent bodies we found as possibly connected to a meteor shower, and for which we have known orbital parameters in a way we may calculate parent body positions back in time. For some cases, numerical integration has been done for only 500 years in the past (since a parent body has not even been close to the Earth's orbit before that time), while for other cases we went back as long as 5000 years.

To summarize: we have found that modeled meteoroids have directly hit the Earth for 8 out of 13 investigated bodies. Some of those bodies are at the moment classified as asteroids, some are comets. Showers and parent body relationships will be presented in details in separate papers. One of the very interesting examples we found is the case of the possible new meteor shower *κ Cepheids* (751 KCE), which we found to be possibly connected to asteroid 2009SG18. According to calculations made by Vaubaillon, we might see some detectable activity on the night of September 21st, somewhere around 3–4h UT (*Figure 4*) from a radiant position around α=328°, δ=+77°.

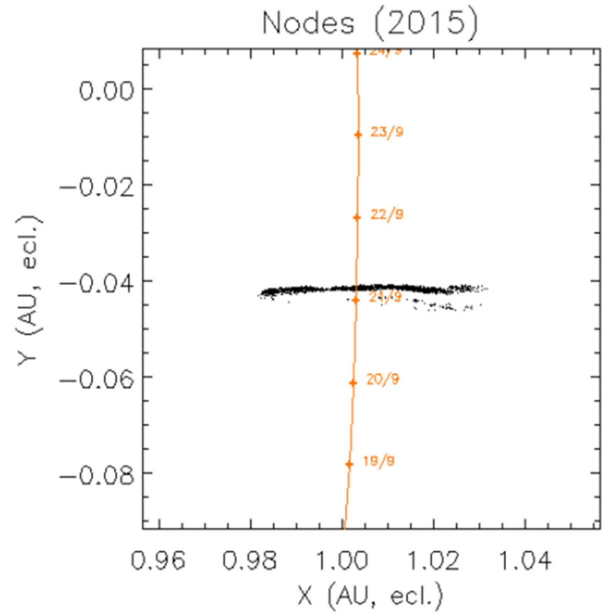

Figure 4 – possible 2009SG18-ids.

7 New fields of research

Telescopic meteors

One of the most common issues when dealing with video orbit data is the precision of observational data and consequently orbital data itself. In order to obtain more precise observations and orbits we decided to use much longer focal length lenses than ordinarily used in video meteor networks (typically 4mm for CMN, 6mm for SonotaCo Network). We did initial estimations on the number of possibly detected meteors in collaboration with Peter Gural, and proceeded with tests of available lenses. We decided to go with the Kowa 55mm F/1.0 lenses which we bought on ebay. Besides Kowa 55mm, we also tested a Canon 90mm F/1.0 lens, but due to a much longer focal length and a higher meteor velocity on the sensor which results in a lower number of detected meteors, we discarded this lens at this stage.

Up to 2015, all CMN stations used 1004X cameras based on 1/3" Sony ICX255 ExView HAD sensor. After last year's paper from (Samuels, 2014), we decided to test cameras we may afford. During the end of 2014 we tested cameras based on Sony ICX633 (ExView HAD), ICX673 (ExView HAD II) and ICX811 (Super HAD II) sensors. The best results were obtained using a camera based on the ICX673 sensor, while the ICX811 sensor based camera was less sensitive (0.2 to 0.3 magnitude difference).One important note when purchasing such cameras – those are usually being sold as “Effio-E” cameras, but this doesn’t mean that the sensor will be ICX673 – check directly with the manufacturer, because “Effio-E” cameras are being sold even with much less sensitive ICX633 sensor. More info about Effio technology may be found online[2].

First tests on double station telescopic meteors were done during the summer of 2014, when we captured on August 2 the first double station meteors with 1004X cameras. Tests were continued with other cameras, up to now there are about 500 telescopic meteors captured from a single station. Typical limiting magnitude from urban area is about 10.5^{mag} for stars (*Figure 5*) and down to about 8^{mag} for meteors.

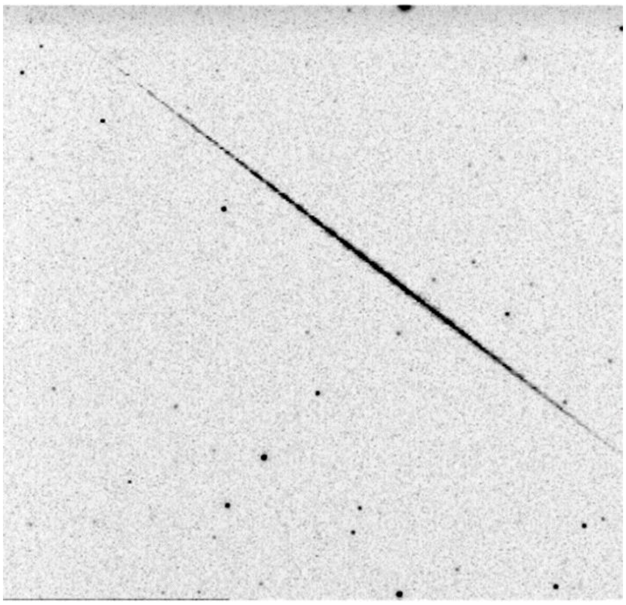

Figure 5 – Telescopic meteor.

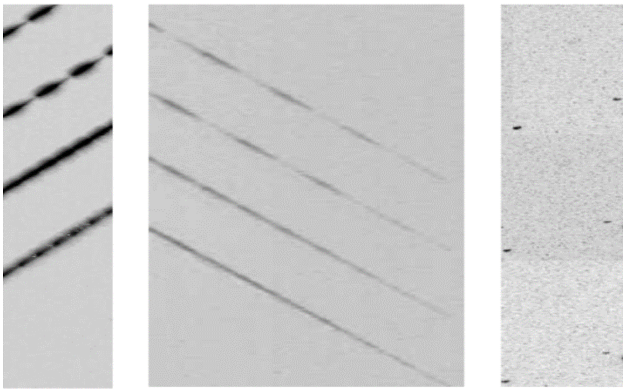

Figure 6 – Telescopic meteor examples.

From the first captured telescopic meteors there has been an obvious need for a new meteor detection procedure. Most important issues (but also advantages for future research) come from the fact that events such as meteor’s wake or meteoroid disintegration are now more clearly visible and significantly affect the centroid position estimation (*Figure 6*). Until proper solutions for these issues are found, we will not publish any data from telescopic observations.

“Rocking chair” meteors

One of “Wacky projects” proposed by Peter Gural at the IMC 2014 in Giron (Gural, 2014) was “the Rocking Chair Camera”. The idea consists in moving the camera at some angular velocity very close to the supposed meteor’s angular velocity (in case of shower meteors) in order to detect fainter meteors and eventually details of the meteor’s wake. Basic setup with a Kowa 55mm F/1.0 lens camera used for initial testing is presented in *Figure 7*.

Figure 7 – “Rocking chair” camera setup.

Although this setup is the one of the worse possible solutions for this purpose (actually, an example how NOT to do it) because of its sensitivity to vibrations, we nevertheless captured a few very interesting meteors. First example is a meteor captured on 26^{th} of December 2014, shown in *Figure 8*. Small variations in linearity of the trajectory are due to the vibration issues, but nevertheless it can be clearly seen that the meteor slowly disintegrated and decelerated as well. The image has been captured at an angular velocity of 5° per second. The other example of meteors captured with this setup (*Figure 9*) is a Perseid captured on the 13^{th} of August 2015 where a wake (?) can be seen during the middle part of the meteor, fading towards the end. This time the angular velocity has been set to 15° per second, to match Perseids’ angular velocity.

We find this new observational method very interesting, but it will take time to develop a setup that would yield valuable scientific data.

[2] http://www.sony.net/Products/SCHP/dsp/products/effio/index.html

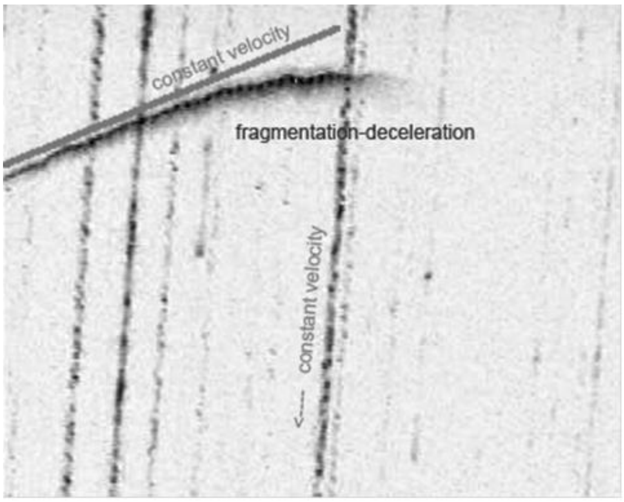

Figure 8 – "Rocking Chair" meteor example.

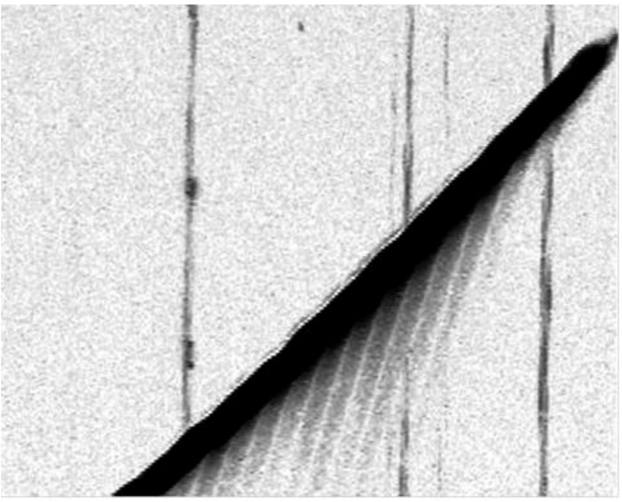

Figure 9 – "Rocking Chair" Perseid.

Raspberry Pi based system

Recent advances in the field of a single board computers enabled the development of a low-cost video meteor station with real-time processing capabilities. Among various models, low-cost Raspberry Pi 2[3] with 4 CPU cores running at 900Mhz in combination with the ICX673 sensor based camera and UTV007 based USB capture device has been used to build an operative prototype. This project has been described in details in Zubović et al. (2015.

A radiometer for everybody

A meteor radiometer is a high time-resolution photometer for measuring sky brightness. As the radiometers have proven to be an invaluable source of data during the fireball fragmentation modeling, and yet there are so few radiometers operational (none of which used by amateurs, as far as the authors are aware), we have built a prototype version using inexpensive photodiodes, operational amplifiers and microcontroller boards. First results are very encouraging, but in order to have some reliable confirmation of our results we still have to wait for the first fireball to be simultaneously detected by our radiometer and the video network. This project has been described in details in Vida et al. (2015). As well as for Raspberry Pi based solution for video meteor observations, this low cost solution may be applied almost everywhere (extremely light-polluted areas excluded).

Neural networks

The neural networks approach has been pointed out as an alternative way for video meteor detection filtering. First steps have been made in that direction, showing it is a very promising way to go. This project has been described in Silađi et al. (2015).

8 Education

From the very beginnings of the Croatian Meteor Network project one of our main goals has been education, mostly oriented towards young people.

One of the students' groups at the Višnjan School of Astronomy (which takes place for more than 25 years) is always dedicated to meteor work. Such approach, working with smaller group of youngsters (*Figure 10*), allows higher concentration on the matter but still develops teamwork skills. Most important, youngsters are being introduced to the scientific method through original (very often their own) observations which adds the value to their work.

During the scholar year of 2014–2015, the CMN enhanced contacts with teachers interested in astronomy, providing necessary data for astronomy contests in Croatia and separate projects. Several CMN cameras are actually situated in schools, and our intention is to spread this collaboration further on deploying new meteor stations.

Figure 10 – The Višnjan School of Astronomy meteor group.

9 Summary

The ongoing work in the Croatian Meteor Network between two International Meteor Conferences has been presented. It is our intention to present CMN work in this way at future IMCs, instead of presenting specific projects in separate talks unless we find them highly interesting to the meteor observing community.

Acknowledgments

Our acknowledgments go to all members of the Croatian Meteor Network, in alphabetical order (first name first): Alan Pevec, Aleksandar Borojević, Aleksandar Merlak, Alen Žižak, Berislav Bračun, Dalibor Brdarić, Damir Matković, Dario Klarić, Dejan Kalebić, Denis Štogl, Dorian Božićević, Filip Lolić, Filip Novoselnik, Gloryan Grabner, Goran Ljaljić, Ivica Ćiković, Janko Mravik, Josip Belas, Krunoslav Vardijan, Luka Osokruš, Maja Crnić, Mark Sylvester, Mirjana Malarić, Reiner Stoos, Saša Švagelj, Sonja Janeković, Tomislav Sorić, VSA group 2014, Zvonko Prihoda, Željko Arnautović, Željko Krulić, as well as Peter Gural. This work was partially supported by the Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, Višnjan Science and Education Center and by private funds of CMN members.

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The author, *Damir Šegon*, during his lecture (Photo by *Axel Haas*).