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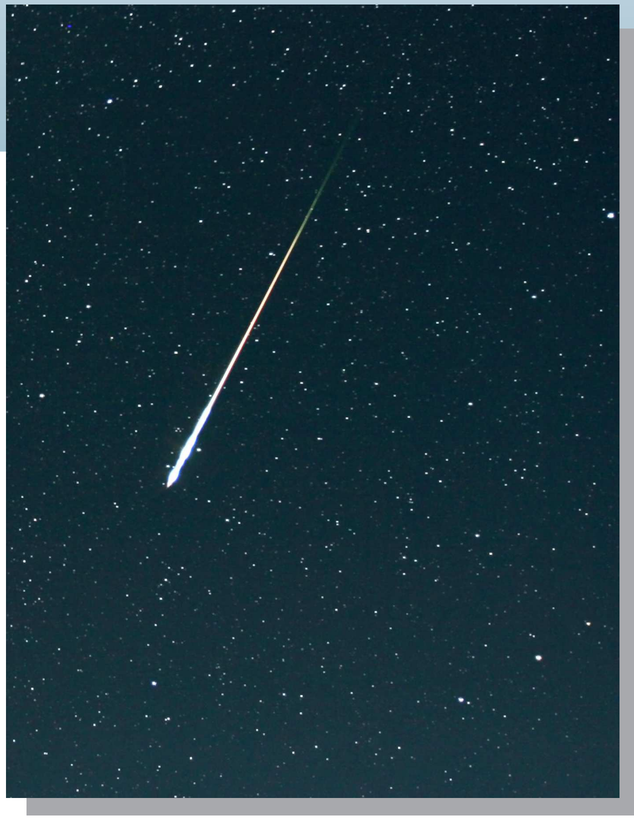

History of the Leonids
Camera calibration
Video meteors

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Front cover photo

A major Perseid fireball captured on the 2006 August 12 morning. This is a single frame with Canon 30D using a 16–35 mm lens (set at 20-mm f/2.8), ISO 400 and 30 s exposure. Ursa Minor is visible right of center. Photo courtesy: Pierre Martin.

Writing for WGN This Journal welcomes papers submitted for publication. All papers are reviewed for scientific content, and edited for English and style. Instructions for authors can be found in WGN **31:4**, 124–128, and at `http://www.imo.net/articles/writingforwgn.pdf` .

Cover design Rainer Arlt

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Editorial

Javor Kac

June ends the school year and signals the start of family vacation time. Many of you are going to be away from school or work in July and August, and this will be a great time to monitor meteor activity.
Given the Moon phase, the best time to observe will be the end of July, the period around the Perseid maximum, and the second half of August. Those in the northern hemisphere will enjoy warm, but short, nights. For observers south of the equator, the highlight of this period will undoubtedly be the Southern δ-Aquarids in the last days of July, combined with the α-Capricornids. I hope that I will also enjoy observing meteors under the starry skies!
For all who want to plan their meteor observations in advance, the IMO 2010 Meteor Shower Calendar is sent with this issue. It will be a great resource for meteor observers in the following year.

International Meteor Conference 2009

The traditional 28th International Meteor Conference in Poreč is nearing quickly. Those that attended IMCs in the past will know it is an unforgettable experience and a must for anyone interested in meteors. For those not familiar with the International Meteor Conferences, an excellent review was written by Roggemans (2006) and some details are on the IMO's *The history of the IMC-tradition* web page: `http://www.imo.net/imo/imc/history`. You will find the IMC is an amazing event, where the meteor enthusiasts from around the world join as a big family. I therefore kindly invite you to participate in the Conference. The registration deadline is end of 2009 August. I am already looking forward to meet old and new friends in September!

Handbook for Meteor Observers reprinted

As the first print of the new Handbook for Meteor Observers (Rendtel & Arlt, 2008) was already exhausted after only 8 months, it was quickly decided to make a reprint, which is now available from the online IMO shop `http://www.imo.net/imo/publications`. The editors took advantage of the occasion to correct some typos and to make minor updates to the shower information where appropriate. The most visible change will no doubt be the much improved quality of the the star maps from the "Atlas Brno 2000".

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Ongoing Meteor Work

Shower Classification Software

Kamil Złoczewski [1], *Mariusz Wiśniewski* [1], *Marcin Lelit* [2], *and Krzysztof Polakowski* [3]

We describe the Shower Classification Software (SCS) which makes an automatic shower classification of plotted meteors. This tool is developed to help observers make shower classification procedure fast and allows them to check calculations done by hand. The programme is available for Linux and Windows operating systems and can be obtained from `http://www.pkim.org/?q=pl/scs`.

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1 Introduction

Observers associated with the Comets and Meteors Workshop (CMW) make most of their visual observations using the plotting technique. We strongly encourage them to make full shower classification analyses of at least 2 to 3 meteors from each night following the instructions given in the IMO Visual Observers Handbook (Koschack et al., 1995). Thus, evaluation of meteor angular velocity is practiced on a regular basis. This practice helps to make reliable not-plotted observations in the nights close to a maximum of the main showers. However, it takes a lot of time to do shower classifications for all plotted meteors from a given night. Moreover, it is assumed that there are no errors done in these calculations. To make this activity faster, easier and more reliable we developed Shower Classification Software (SCS). SCS is compatible with Polish Visual Meteor Database, for data in the format of IMO's Visual Meteor Database one can use Visdat package (Richter, 1999) that offers similar functionality. In the following sections we describe SCS programme and show the results of SCS tests.

2 SCS description

SCS takes input from files made using Corrida software written by Michał Jurek (available at `http://corrida.pkim.org`) and needs five other files containing: shower information; radiant positions during the year (based on the Table 6 in the IMO's annual Meteor Calendar); ecliptic shower information for Antihelion (Jones & Brown, 1993), Southern Taurids and Northern Taurids showers (Triglav, 2001); observing site positions; and solar longitude table. The programme uses the information contained in the Corrida's output files which are in the format of the Polish Visual Meteor Database (Olech et al., 2001; Złoczewski et al., 2009). Then it checks association criteria for every meteor with all meteor showers active during the given time. This includes: altitude of the radiant; length of apparent meteor path; meteor trace-back criteria (including change of the radiant size with the meteor-radiant distance); and the velocity criteria (Koschack et al., 1995). The plotted meteor is classified to the best matching shower according to the best agreement of the velocity criteria. If it does not match any of the active showers it is classified as a sporadic (SPO) event.

We use spherical trigonometry to measure distances and calculate angles on the sky plane. Radiant diameter changes as it is written in the Handbook (Koschack et al., 1995). Error of angular velocity estimates are now fixed at value 5°/s for $\omega < 27^\circ$/s and 8°/s for larger velocities. IMO's solar longitude tables are used to calculate interpolated solar longitude of meteor event, showers activity period and their positions (for the time of meteor event).

Ecliptical showers are approximated by three circular showers located at the same ecliptic height. SCS gives an output of meteor classification on the screen and in two files: the 'class' file which summarize classification and the 'log' file which shows results of all calculations made. Additionally, the user can choose to calculate radiant positions using IMO's annual Meteor Calendar or order SCS to compute coordinates itself (a crude assumption of 1 degree/day drift in the solar longitude is used).

3 Shower Classification Software test

We tested SCS during CMW's XIX Summer Observing Camp in July 2008 which was held in the North Observing Station of the Warsaw University Observatory located in Ostrowik. We used visual plotted observations of nine CMW's observers (Marcin Chwała, Hubert Donhefner, Barbara Handzlik, Marcin Lelit, Mariusz Lemiecha, Krzysztof Polakowski, Magdalena Sieniawska, Paweł Swaczyna and Kamil Złoczewski) who made $T_{\rm eff} = 66.53$ h during 7 nights between 2008 June 29/30 and July 11/12. According to IMO's annual Meteor Calendar the following meteor showers were active (some only during one night) during this period: Antihelion Source; June Bootids; α-Capricornids and Southern δ-Aquarids. The following test compares the abilities of visual observers to make shower associations manually with the automatic association procedure. Observers were asked to enter their reports with Corrida software and write down all estimates crucial for classification by hand: estimate size of the radiant, radiant-meteor distance and height of its beginning above horizon using round sky map. Then observers had to use derived values to predict angular velocity of

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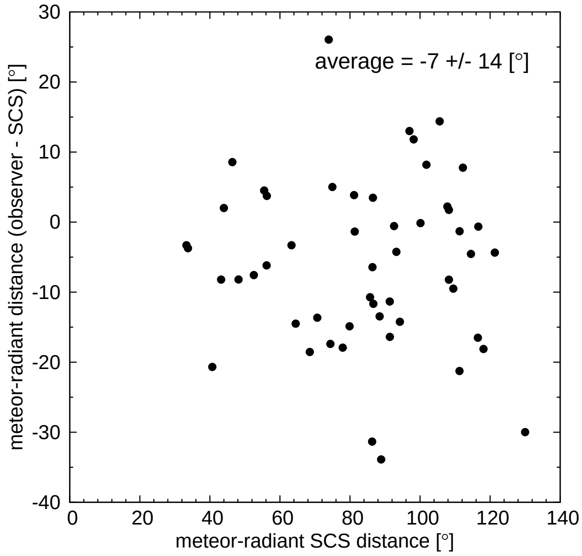

Figure 1 – Comparison of meteor-radiant distances derived by observers and SCS.

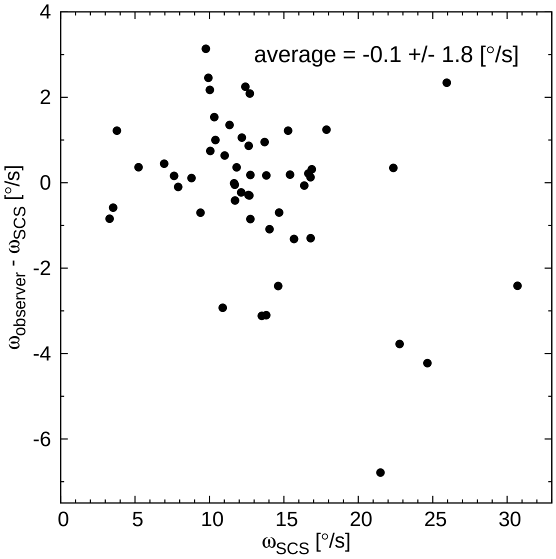

Figure 2 – Comparison of angular velocities derived by observers and SCS.

the meteor event for the given shower and compare it with its observed angular velocity. In total, 355 plotted meteors were analysed, most of them did not hit any active radiant while tracing their path back and were classified as sporadics instantly. Fifty-two events were checked further, in the way described in the IMO Handbook and 30 of them were associated with one of the active radiants. We compared classification of all 355 meteor events done by observers and using SCS. Only 21 events were wrongly associated by observers: 7 were wrongly classified as sporadic events, 14 events were wrongly associated among active showers. One can note that nearly half of classifications of non-sporadics done manually did not match those computed by SCS. We went through all 21 cases and found that 11 events were wrongly or even not extrapolated by the observers. Other discrepancies in the identifications were due to wrong angular velocity estimates or size of the radiant (wrong distance estimates).

The number of 14 events wrongly associated by observer as CAP or ANT were indeed CAP (observer identified as ANT), ANT (observer identified as CAP) or sporadic (observer identified as ANT or CAP) meteors. The main reason is because ANT and CAP radiant positions are quite close to each other so the radiant identification can be easily spoiled by observational and calculation errors.

In Figure 1 we present difference between the observers' estimate and SCS calculation of meteor-radiant distance as a function of the meteor-radiant distance derived with SCS. In Figure 2 we show the same comparison for the angular velocity. Note that observers tend to underestimate meteor-radiant distance value and in some cases observers made crucial errors. Additionally, it can be seen that the spread in the radiant-meteor distance determination using round sky map (non-gnomonic) is quite large – roughly 20° – and remains roughly constant for SCS radiant-meteor distance 40°–120°. In case of angular velocities, discrepancies are smaller and only a few estimates are totally different in comparison with the automatic calculations.

4 Summary

We presented the SCS programme which makes classifications of meteor events following the recipe given in the IMO Visual Observers Handbook. Programme was successfully tested using real observations. We have briefly mentioned the main pitfalls and small errors made by visual observers. The programme can be recommended to use as an alternative for meteor-shower classification by hand.

Acknowledgement

We would like to thank Prof. Marcin Kubiak from Warsaw University Observatory for allowing us to organize the CMW astronomical camps in Ostrowik where the majority of our data was collected.

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How many stars are needed for a good camera calibration?

Damir Šegon [1,2]

A new calibration procedure has been implemented for the Croatian Meteor Network's cameras, which is based on a sequence of measured calibration stars over the course of a night. The analysis shows that if the camera's field of view is not uniformly covered with reference stars, there is a discrepancy in residuals between the model fit and the actual observations.

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1 Introduction

The Croatian Meteor Network (CMN) has been doing camera calibration using Seiichi Yoshida's PIXY software (Yoshida, 2005) on 6 to 8 manually selected and stacked images selected from an entire night's session, usually containing about 150–200 stars. With the recent application of the new MTP detection software (Gural & Šegon, 2009), it is now possible to combine stars from all the images captured on different nights into a single calibration fit. This includes over 10 000 star position measurements under the assumption that the camera is fixed in position and pointing direction from night to night. Thus it is now possible to do more precise error estimation and an analysis of the impact of the number of stars on the camera's calibration quality. This paper presents the analysis results applied to 15 CMN stations.

2 Method

The method of overlapped star fields has been used for quite some time to calibrate a camera's field of view (FOV) as pointed out in (Eichhorn, 1988). Basically, one takes time separated snapshots of a drifting star field and calculates stellar deviations from a model fit in a gnomonic projection space, and by using these data calculate the optical deformations. In our case, a fixed meteor camera provides one image every minute, so during the night we have somewhere between 350 (summer) and 750 images (winter). The MTP_Detector software generates a database containing the centroids of the brighter stars in each image. The stars are identified to obtain their right ascension (RA) and declination (Dec) and appear in multiple frames during the night drifting across the field of view. A reference image is selected and any star's RA is corrected for the hour angle difference relative to that reference image's time. This correction allows one to use all the measured stars from all the images as if they were detected on a single frame. The result is that the number of star positional measurements available for a given CMN camera's FOV calibration dramatically increases to be more than 10 000 (see Figure 1)!

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Of course it is not only the number of stars that provides a good camera calibration, but that these stars should be more or less uniformly distributed over the entire FOV. It is well known that not all parts of the sky have a uniform star distribution, so our approach is to calibrate our cameras on parts of the sky which are more populated with stars, and then use these calibration parameters on the actual FOV. This is the main reason we use a method described in (Yoshida, 1997). The difference between this method and the classical Turner's method is that one finds the RA, Dec, scale and positional angle (rotation of the camera) before calculating the optical deformation's parameters – by finding these initial parameters by linear fit (Steyaert, 1990). The actual star matching is done by first using measured values from the PIXY software based on the best quality image that usually contains 35–40 stars. This is aligned with a third-order polynomial fit. After associating and matching stars between multiple frames (starting with a rejection radius of 3 pixels and ending with 0.75 pixels), new fitting coefficients are calculated for the entire multi-frame image set.

We have found for the CMN cameras with a $64^\circ \times 48^\circ$ FOV that a third-order polynomial approximation with barrel distortion corrections in the X and Y axes, represent the best fit for our 4-mm f/1.2 lenses. Lower-order polynomials such as linear and quadratic show large mean errors of the order of 8–10 arc minutes (about 1 pixel), while fifth order does not show any significant improvement over third order.

The typical observed minus calibrated (O-C) diagram when plotted versus radius from the image center, shows that star positions are well calibrated across

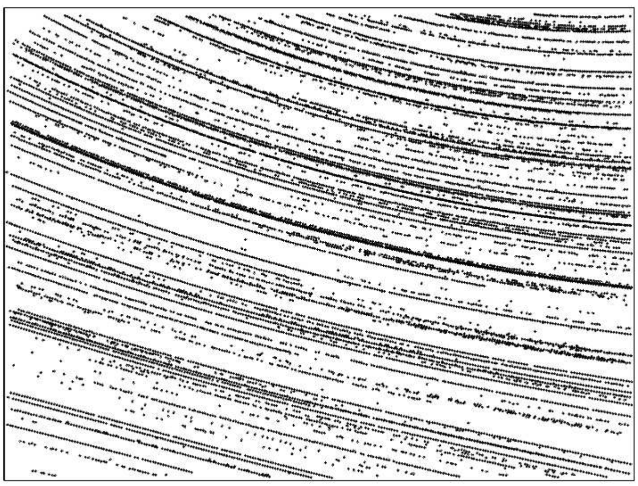

Figure 1 – Example of multiple positions of star measurements as many stars drift across the field of view.

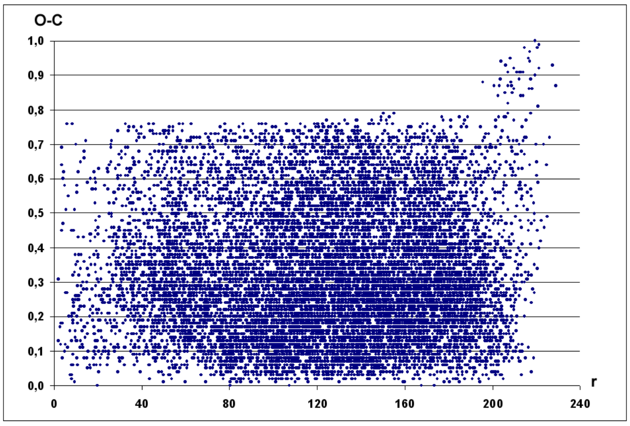

Figure 2 – Positional errors as a function of radius from the image center.

almost the entire field of view (Figure 2). Only the extreme corners of the image show mildly increased error, but that is mainly due to coma which degrades the measurement centroid estimation, and a better quality lens replacement in the future should help resolve this issue.

3 Single calibration using an entire night's data

The method described above has been applied to imagery collected from 15 CMN cameras. Nights with different types of weather and seeing conditions had been chosen, so that different numbers of stars contributed to the calibrations. Results are presented in Table 1 and Figure 3.

We note that in general, when the minimum star number used for calibration exceeds 1700, the mean errors do not depend on the number of stars used, and have an average value of around 0.35 pixels.

4 Calibration using data from single images and their combinations

The old CMN calibration method was based on 6 to 8 stacked images (about 150–200 stars), with a third-order polynomial fit without barrel correction. It is now possible to compare how accurate the earlier method was and determine if there is the possibility to improve the previous data reduction results. Using the

Table 1 – Mean error calibration results for 15 CMN cameras.

Station	Stars	(O-C)	std
Merenje	5 239	0.28	0.33
Mali Lošinj	5 991	0.34	0.39
Osijek	4 710	0.32	0.37
Petrovsko	8 344	0.35	0.40
Pula A	13 321	0.33	0.38
Pula B	9 020	0.36	0.40
Rijeka A	8 661	0.36	0.40
Rijeka B	10 301	0.34	0.39
Šibenik	16 344	0.35	0.40
Varaždin	2 628	0.34	0.38
Višnjan	11 842	0.34	0.39
Valpovo	1 716	0.35	0.40
Velika Pisanica	5 466	0.39	0.44
Žrnovnica	4 534	0.36	0.41

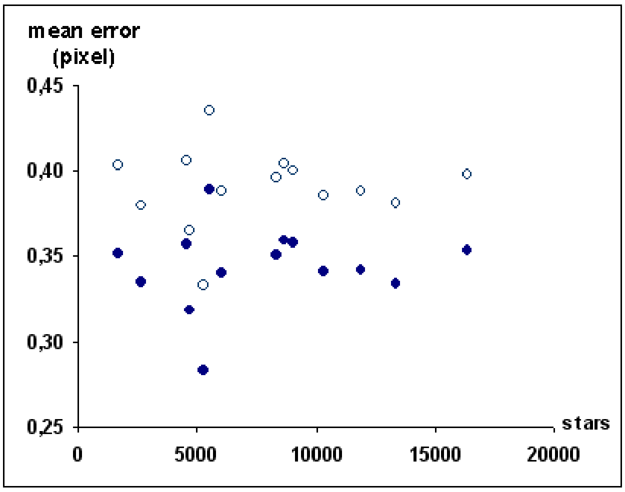

Figure 3 – Graphical presentation of results from Table 1.

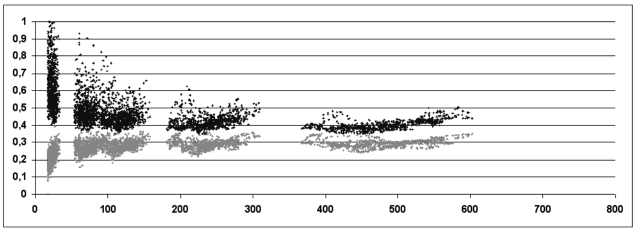

Figure 4 – Mean error (pixels) versus number of stars used for calibration on stars from consecutive images.

entire night's initial values for RA, Dec centroids, and the camera rotation and scale, the calibration has been done for single images containing more than 18 matched stars. After that, stars from 3, 5, 10 and 20 consecutive images had been used for calibration. Error estimation has then been done on stars from the entire night as well as only those star/image sets used for a particular calibration. Typical results are shown in Figure 4, where each dot represents the calibration's mean errors based on reference stars from 1 to 20 image combinations (black) and the whole night (grey), respectively.

To find out if it is possible to get improved calibration using combinations of images taken with greater temporal separation, instead of stars from consecutive images closely spaced in time, we repeated calibrations on stars from 3, 5, 10 and 20 images separated by at least 20 minutes between individual frames. Error estimation has then been applied on stars from the entire night as well as for stars used only for the calibrations. Results are shown in Figure 5, where black and grey dots represent each calibration's mean errors based on reference stars from images combination's and whole night, respectively.

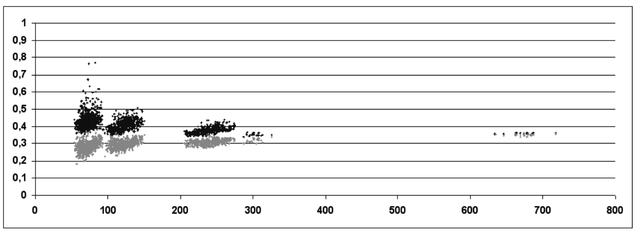

Figure 5 – Mean error (pixels) versus number of stars used for calibration on stars from images separated by at least 20 minutes.

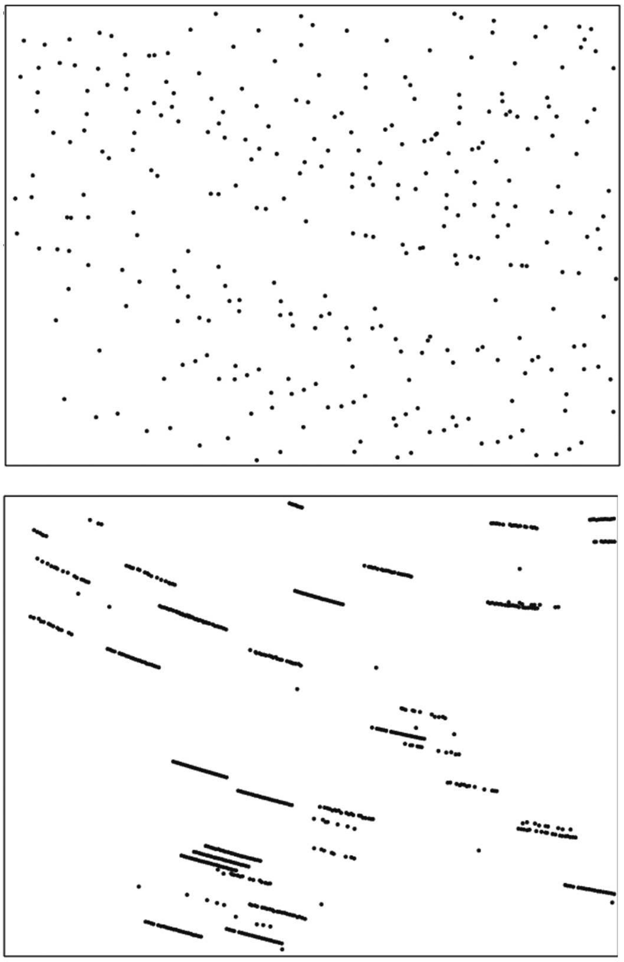

Figure 6 – 304 stars from images 20 minutes apart (top) versus 611 stars from images adjacent in time (bottom); it is obvious that FOV coverage is better for the combined images separated by at least 20 minutes.

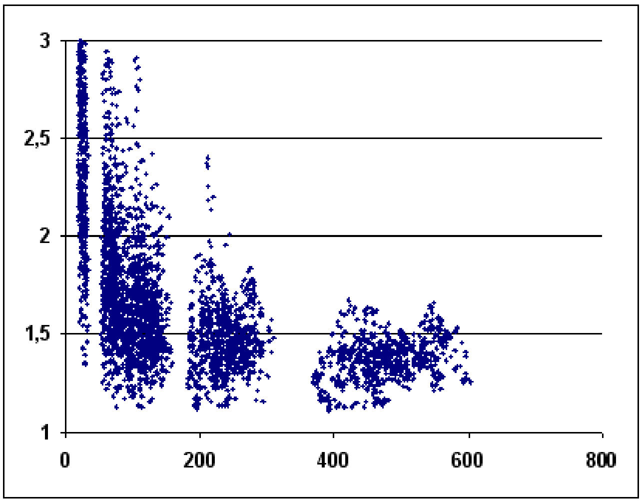

Figure 7 – Error ratios as a function of the number of stars used for calibration – stars from consecutive images.

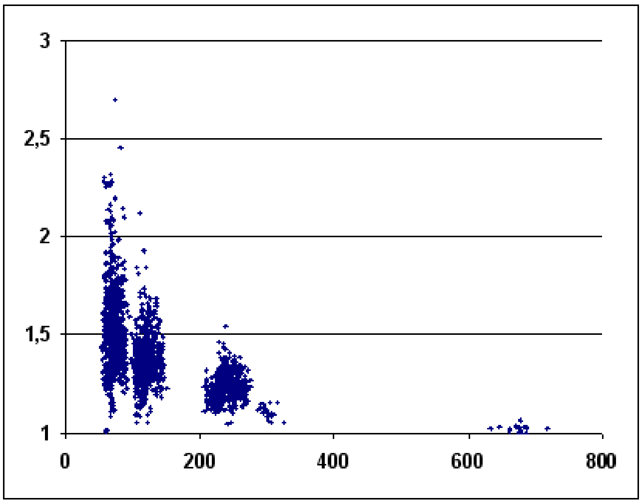

Figure 8 – Error ratios as a function of the number of stars used for calibration – stars from more greatly separated images in time.

5 Discussion

Results for consecutive images shows that despite more stars being used than from a single image, calibration errors from just a few frames do not drop to the values we get from combining a whole night's measurement set. This can be most easily explained by noting that an uneven star distribution over the FOV gets more filled in uniformly with the larger full night data set (Figure 6). This is confirmed if we look at data for the combined images separated by at least 20 minutes. Results are far better than more closely spaced images and we can obtain reliable results with only 300 stars (5–10 images in our case).

However, error analysis also shows that the mean error and standard deviation estimates computed from fewer stars are underestimated. It means that one should not rely on error estimation results based only on the stars used for the calibration. The real error should be based on residuals from stars detected for the entire night. In our case, the real error ratios as a function of the number of stars used for calibration for the two cases (consecutive and temporally separated reference stars sets) is given in Figure 7 and Figure 8, respectively.

It can be seen that only about 300 stars from temporally separated images are required for reasonably good error estimation. Calibrations from consecutive (adjacent in time) images are not reliable even with 600 reference stars because of the near redundancy in the star measurements over short spans of time. In this light, we can presume that results from the old CMN calibration method are not as accurate as once believed. While calculated mean calibration error was arround $0.^\circ05$, according to Figure 7, we can now estimate that the real mean error in calibration was more probably about $0.^\circ07$ or worse.

There is another issue that popped out during this analysis which we nicknamed "star wobbling". Despite using a very accurate centroid estimation algorithm as implemented in the MTP_ Detector, faint stars showed variable residual distances from image to image relative to their predicted calibration positions. After some consideration, we identified two possible causes.

The first may be due to atmospheric scintillation, since in our case, star images span at least 2 pixels, and intensity variations cause the centroid to shift relative to the true location. If calibration is performed on fewer stars than has been recommended herein, this may cause significant errors. However, if we have plenty of stars, this effect averages out and becomes negligible

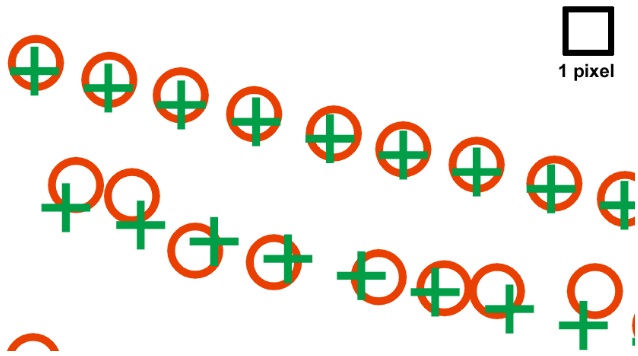

Figure 9 – “Star wobbling” effect, it can be seen as uneven distances in centroid detections. Crosses represent calculated positions, while circles represent actual detected centroids positions. It can be seen that the brighter star (near the top) show smooth, regular residuals while fainter stars (bottom sequence) shows irregular jumps. However, fainter star’s calculated positions follow the actual star’s path very good.

(see Figure 9). If that is the main reason, then camera systems using single frames (1/25 second integration time) for centroid calculations should not suffer from wobbling, since variations in scintilation do not affect the centroid position as significantly as during a one-minute exposure.

The second cause may be due to the camera’s resolution and/or non-uniform single pixel sensitivity. In such cases, this effect should have been noticeable even on single frames. This is still an area of investigation that is limited by our image capture and archiving approach so it is not possible to evaluate at this time. In both cases, meteor detections and track estimation are not seriously affected by these effects – only extremely faint and short meteors to some degree.

If we do an error analysis as a function of magnitude, results show that stars between first and third magnitude provide a much better fit to the calibration model, while fainter stars show bigger errors. As demonstrated earlier in this paper, a calibration based on an entire night’s star positional measurements yields an average error for the CMN cameras that does not exceed 0.35 pixels or roughly 4 arc minutes. However, if we consider the wobbling effect, things look different. The mean error on brighter stars is less than 0.3 pixels as indicated in Tables 2 and 3. We can estimate that the real mean calibration error does not exceed 0.3 pixels or $0\overset{\circ}{.}05$.

6 Conclusions

A re-analysis of the old CMN calibration method shows that there is room for improving the previously reduced data sets and this will be done in the future. More than 10 000 stellar positions across a given camera’s focal plane can now be used for the FOV calibration of a single-station camera. The new method allows FOV calibration down to a mean error of $0\overset{\circ}{.}05$ when using a 4-mm f/1.2 lens ($64° \times 48°$ FOV). This is equivalent to a subpixel accuracy of 0.3 pixels. It is also important to note that error estimates based on single (or limited combinations) of an image data set over short spans of time should be assessed with caution. About 300 stars with several images each temporally separated by at least 20 minutes should be used to obtain good calibration for cameras and lens combinations like those used by the CMN.

Acknowledgements

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Table 2 – Cumulative magnitude range mean calibration error estimation.

to mag	stars	(O-C)	std
1	936	0.23	0.27
1.5	1 459	0.23	0.27
2	3 235	0.26	0.30
2.5	4 516	0.28	0.32
3	8 042	0.31	0.36
3.5	10 193	0.33	0.37
4	11 472	0.34	0.38
4.5	11 842	0.34	0.39

Table 3 – Magnitude range mean calibration error estimation in 0.5 mag steps.

m_1 - m_2	stars	(O-C)	std
0.5–1.0	460	0.23	0.26
1.0–1.5	523	0.23	0.26
1.5–2.0	1 776	0.28	0.32
2.0–2.5	1 862	0.34	0.38
2.5–3.0	3 704	0.35	0.39
3.0–3.5	3 434	0.38	0.42
3.5–4.0	2 049	0.43	0.47
4.0–4.5	512	0.45	0.49

History

The Leonid meteor shower and the history of the Semites (Arabs and Jews)

Mohammed Omar Suleyman [1]

Every 33 years, when Comet Tempel-Tuttle returns into the inner Solar system, the Earth crosses the most compact part of its dust swarm and this sometimes causes a heavy meteor shower. This paper investigates two legends of the Semites and tries to prove their connection with the ‘stars shower’. The first legend, connected with the history of the Arabs, tells about the miraculous rescue of Mecca when flocks of birds dropped small stones on the army of Abraha and masses of his warriors died. The second legend, connected with the history of the Jews, says that the seventh plague which God sent on Egypt at the behest of Moses was a heavy fall of hail. In this paper we argue that the ‘stars shower’ of the Leonid meteor stream was responsible for the two phenomena observed in those two legends, and this happened respectively on 569 AD October 8th and 1226 BC August 15th.

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1 Introduction

The Earth’s passing near the orbit of Comet 55P/Tempel-Tuttle every year in November each time results in the so called ‘stars fall’, known as the Leonid meteor shower. In normal years the activity of the Leonids is up to a few meteors per hour. But in the years when Comet Tempel-Tuttle returns near the Sun, the Earth crosses the most compact part of its dust swarm, and this causes the ‘stars shower’. This happens about every 33 years.

The flux of the Leonid meteor shower depends on the moment of the comet’s passing through the point of intersection of its orbit with the plane of the Earth’s orbit (i.e. its node), the moment and the minimal distance of the Earth’s passing this point, and the spatial number density of the particles in the stream at that moment and location. Depending on the shower rate, the ‘stars rain’ is conventionally divided into ‘light stars rain’, ‘heavy stars rain’, and ‘stars shower’ (Cherhovskij, 1998).

In 1885 Kirkwood considered the existence of three compact meteoroid streams in the orbit of the Leonids with periods $P = 33.25$ years, $P = 33.31$ yr and $P = 33.11$ yr respectively (Kazimirčak-Polonskaja et al., 1968). Table 1 lists all the ‘stars rains’ of which we have any record since 902 AD according to Cherhovskij (1998). If we exclude the ‘light stars rain’ from this list, we can get the period (P) of recurrence of the ‘heavy stars rain’ or ‘stars shower’ (Table 2). The results confirm Kirkwood’s assumption.

Newton gave a formula for the expression of the secular drift of the Leonids’ node (Astapovich & Terenteva, 1966):

$$\Omega = 232^\circ 41'\!.6 + 1'\!.728(T - 1900),$$

where T is the year of observation.

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2 The first story

Quran – Chapter 105 (The Elephant) – Sura 105 (Al Feel)

بسم الله الرحمن الرحيم
الم تر كيف فعل ربك باصحاب الفيل
الم يجعل كيدهم في تضليل
وارسل عليهم طيرا ابابيل
ترميهم بحجارة من سجيل
فجعلهم كعصف ماكول

Bismillaahir – Raḥmaaniir – Raḥiim
105.1 ’Alam tara kayfa fa-‘ala Rabbuka bi-’aṣ-ḥaabil-fiil?
105.2 ’Alam yaj-‘al kaydahum fii tadliil?
105.3 Wa ’arsala ‘alayhim ṭayran ’abaabiil,
105.4 Tarmiihim - bi - ḥijaaratim-miñ-sijjiil,
105.5 Faja ‘alahum ka-‘aṣfim-ma’-kuul.

translated by Shakir (Quran) as:

In the name of Allah, the Beneficent, the Merciful.
105.1 *Have you not considered how your Lord dealt with the possessors of the elephant?*
105.2 *Did He not cause their war to end in confusion,*
105.3 *And send down upon them birds in flocks,*
105.4 *Casting against them stones of baked clay,*
105.5 *So He rendered them like straw eaten up?*

This Sura of the Quran, ‘Al Feel – The Elephant’, tells about the campaign of the Ethiopian viceregent in Yemen named Abraha Al Ashram (Abraha, nicknamed gap-toothed) against Mecca in 570 AD, and the miraculous rescue of the town. This Sura, which is really one of the most beautiful Suras of the Quran, contains the story of the intention of Yemen’s ruler to destroy the Kaaba, take away its sacred idols to Yemen and proclaim his capital as the religious centre of Arabia. This had many advantages because it would mean that for the first, seventh and last months of the year the town would be not only the pilgrimage centre, but also a trading centre of all the Arabic tribes.

Table 1 – List of all the 'stars rains' since 902 AD.

1966	+
1965	∗
1932	•
1901	∗
1900	∗
1868	∗
1867	∗
1866	∗
1833	+
1832	∗
1799	+
1798	∗
17xx	
17xx	
1698	•
1666	•
16xx	
1601	∗
1566	∗
1533	∗
1532	∗
1498	•
1466	•
14xx	
1xxx	
1366	∗
13xx	
1xxx	
12xx	
1238	∗
1202	∗
11xx	
11xx	
1xxx	
10xx	
10xx	
1002	∗
967	•
934	•
902	∗

• light 'stars rain'

∗ heavy 'stars rain'

+ 'stars shower'

Table 2 – The period of recurrence of the heavy 'stars rain' or 'stars shower'.

1966 – – 1833	$\bar{h}$ 33.25	$\bar{h}$ 33.31	$\bar{h}$ 33.25
1799 – – 1533	$\bar{h}$ 33.25		
1533 – – 1202	$\bar{h}$ 33.1	$\bar{h}$ 33.21	
1202 – – 902	$\bar{h}$ 33.33		

Ethiopian troops participating in that campaign had battle elephants – an animal unknown in Arabia before that. Those elephants impressed the imagination of the Meccans to such an extent that the year of the Yemen-Ethiopians' campaign against Mecca was named 'The Year of the Elephant' (Panova & Vahtin, 1990; Piotrovskij, 1991). 'The Year of the Elephant' was used by the Arabs as the beginning of their chronology for 68 years – till 638 AD, when Caliph Omar Ibn Al Khatab introduced the lunar Hijra as the official calendar, which is dated from 622 AD July 16th – the date of the migration of the Prophet Mohammed from Mecca to Medina (Tsybulsky, 1979; Klimishin, 1990).

The Prophet Mohammed was born on the 29th of August in 'The Year of the Elephant' (Bolshakov, 1989).

The legend tells that the Yemen-Ethiopian troops were great in number, and the Meccans were not strong enough to withstand them. Therefore, at the approach of the troops to Mecca, the Meccans, with their women and children, left the town for the nearby mountains, leaving Mecca without defence. In the town remained the curator of the Kaaba, Abdal Muttalib Ibn Hashim – the grandfather of Mohammed – and some respectable persons, for the parley with Abraha. But Abraha stopped at the outskirts of Mecca, as some of the tribes participating in the campaign refused to enter The Holy Land with weapons in hand. (That was the territory with the centre in Mecca and a radius of about 100 kilometres where it was forbidden to fight.) At that time a miracle happened: flocks of birds fell upon the troops and dropped small stones on them which left painful wounds on the bodies of the warriors. Masses of people died agonizing deaths, the idea of capturing the defenceless Mecca was abandoned and the enormous army of troops marched away in a hurry. The heavy rains which burst soon after washed away the remaining troops of Abraha directly to the Red Sea (Piotrovskij, 1991). Thus it is believed by tradition that God saved Mecca from the aggressor.

Now we study in detail the Sura 'Al Feel' and try to find out what really happened to the troops of Abraha. The first and second verses do not need any discussion. Let us study the third verse:

105.3 *And send down upon them birds in flocks,*

In the Arabic language the verb 'tara' means 'fly'. From this we get the word 'tair' meaning 'flying' (i.e. adjective), while a word meaning 'bird' as noun is absent in Arabic. The word for plural 'birds' is 'tayr'. Who can throw stones from the sky? Of course the one that flies. In other words, the word 'tayr' here does not necessarily mean 'birds'. It might simply be meaning 'flying objects'.

The fourth verse:

105.4 *Casting against them stones of baked clay,*

The [flying objects or birds] are casting on the warriors stones of 'sijjiil'. The word 'sijjiil' in the Arabic language is used in the Quran only. It has not survived anywhere else, and its exact meaning is not known. Elsewhere, in chapter 11, 'The Holy Prophet' – 'Sura Hood', about the annihilation of the people of Lot in verse 82 –

فلما جاء امرنا جعلنا عاليها سافلها وامطرنا عليها حجارة من سجيل منضود

11.82 Fa-lammaa jaaa-'a 'amru-naa ja-'alnaa 'aali-yahaa saafilahaa wa 'amṭarnaa 'alay-haa ḥijaa - ratam - miñ - sijjii - lim-mañduud, —

11.82 *So when Our decree came to pass, We turned them upside down and rained down upon them stones, of what had been decreed, one after another.*

– Shakir (Quran) just ignores the word 'sijjiil'.

The famous arabist I.U. Krachkovski in his Russian version of the Quran (Quran, 1986) translated 'sijjiil' in the first verse the same as Shakir 'обожженная глина' – 'baked clay', but in the second verse he translated it as 'глина плотная' – 'compact (or dense) clay'.

It should be noted that in the first verse the stones of 'sijjiil' are thrown by the birds, while in the second verse they are rained down.

The last verse:

105.5 *So He rendered them like straw eaten up?*

The translation of Shakir (Quran) is not exact because what he translated as 'straw eaten up' – 'aṣfimma'-kuul' should be translated as 'stormed field of eaten up straw'. It is traditionally understood as the 'smallpox' which attacked the army of Abraha. Krachkovski for example in the commentary to his Russian version of the Quran writes: 'Usually explained by smallpox' (Quran, 1986).

But as we can see from the text of the fifth verse there is no hint of 'smallpox' there. Where did the idea of smallpox come from? Most probably it came from the legend and stories. Actually the first record of an outbreak of smallpox in Arabia was mentioned approximately at that time (Panova & Vahtin 1990). So it might be a fact that an epidemic of smallpox really attacked the army of Abraha, but, as we can see here, there is not a word about that in the Sura 'The Elephant'. In fact the legend about Abraha's death says that after his return to Yemen he died of his body bursting out of wounds on his skin.

Now — what actually happened?

Coming back to the three verses together, we shall generalize the situation: something flying in the sky (a lot of it – flocks), and throwing [stones] of [baked clay], from which the warriors ran away leaving the camp like a stormed field of eaten up straw. It is not difficult to separate the facts from fantasy in this story.

Facts: Burning bodies flying overhead in the sky. As a result the warriors ran away in panic.

Fantasy: The falling bodies are thrown by flying objects (birds), and they seemed to be stones of 'baked burning clay' cooling down while reaching the ground. These stones killed the warriors, and since there were no corpses left, that meant that the heavy rains washed them away to the Red Sea as legend says.

And in fact the following happened:

The army of Abraha approached Mecca from the west – the Red Sea's side. The Meccans fled to the mountains on the east of Mecca. Abraha could have taken the defenceless Mecca by directly marching on it, but he stopped at the approach to the Holy Land because of the refusal of the Arabic tribes to proceed. Soon an epidemic of 'smallpox' started in Abraha's camp, and it was brought by the Ethiopian warriors from its place of origin – Ethiopia. During the night strange things began happening, something unbelievable – thousands of bright objects flying overhead in the sky. The warriors of Abraha decided that it was the time for God's punishment for their great sin – their intention to destroy God's temple, the Kaaba. They ran away in panic. Abraha was compelled to turn his army around and march back to Yemen.

The Meccans in the mountains, when they saw the bright bodies falling from the sky in the westward direction where Abraha was camping, not far from the Red Sea, decided that their Almighty God was saving the Kaaba and destroying the aggressors with burning stones. The Meccans descended from the mountains, and not finding a field of dead bodies, they decided that the waters of the heavy rains had swept them away together with the rest of the army to the Red Sea.

We now come to the main question: what was falling from the sky during that night?

In order to answer this question we have to determine the time of the year when those events happened. Two hundred years prior to Islam the Arabs partially adopted the Jewish calendar which began in September (Klimishin, 1990). This means that 'The Year of the Elephant' probably began in 569 AD September and continued till 570 AD September. In that year two more events of great importance in the history of Yemen happened.

First event: The waters broke the Ma'rib Dam near the capital of Shaba – Ma'rib (Piotrovskij, 1991). Thanks to that dam the adjacent lands were irrigated, and that area was called 'Happy Yemen'. That catastrophe, which was mentioned in the Quran, caused a mass resettlement of the tribes from that region and the fall of the state. Till now the Arabic-speaking people have a saying, 'The people scattered like the tribes of Shaba.'

Second event: In that year Yemen was invaded by a big Persian force, who quickly defeated the Ethiopian army and its local allies, and affirmed the supremacy of Persia in southern Arabia for some scores of years (Panova & Vahtin, 1990).

According to these facts and the information about the rainy season in central and southern Arabia, four arguments might be applied to restore the historical sequence of those events:

Table 3 – Correlation of 'The Year of the Elephant' with the period of recurrence of the heavy 'stars rain'.

902 – – 569	$\bar{h}$ 33.33
1202 – – 902 – – 569	$\bar{h}$ 33.32
1533 – – 1202 – – 902 – – 569	$\bar{h}$ 33.24
1799 – – 1533 – – 1202 – – 902 – – 569	$\bar{h}$ 33.24
1966 – – 1799 – – 1533 – – 1202 – – 902 – – 569	$\bar{h}$ 33.26

1. The campaign of Abraha against Mecca could not happen following the catastrophe – the rupture of the Ma'rib Dam, i.e. the vital construction of the country.

2. The Persian invasion was possible due to the weakness of Yemen caused by the failed campaign of Abraha to Mecca and the destruction of the main dam.

3. The rains, which allegedly washed away the army of Abraha, might have happened in late autumn or winter, as this is the only rainy season in central Arabia.

4. The rains, flooding the Ma'rib Dam, might have happened in the spring only. (There are two rainy seasons in Yemen – spring and autumn.)

It would only be logical to make the following conclusion regarding the historical sequence of the events in 'The Year of the Elephant":

569 AD September = The beginning of 'The Year of the Elephant'.

569 September – 570 January = Abraha's campaign to Mecca.

570 February – 570 April = The destruction of the Ma'rib Dam.

570 summer = Landing of the Persian force in Yemen.

570 August 29th = The birth day of the Prophet Mohammed.

570 September = The end of 'The Year of the Elephant'.

What happened in the sky over Mecca in the autumn of 569 AD that frightened the warriors of Abraha to death, and that the Meccans interpreted as a miracle? Likely it was the Leonid meteor shower.

Table 3 shows that the year 569 AD is in good correlation with the period of recurrence of 'heavy stars rain' ($P = 33.25$ years). Moreover, we can note the direction of the allegedly falling objects, from over the heads of the Meccans to Abraha's camp, that is to say, east-west, or north east to south west which is the direction of the Leonid shower. We also note that the events happened in autumn. Now just imagine the camp of Abraha on 569 AD October 8th [by Newton's formula (Astapovich & Terenteva, 1966), in the sixth century the maximum of Leonid meteor shower fell on October 7–9th] on the twelfth day after the new moon (in 569 AD September the new moon was on the 26th). The epidemic of smallpox had just begun in the camp of Abraha. The warriors were afraid that the God of the Kaaba would surely punish them and rescue the sacred site. Just at that time the Leonid 'stars shower' began. Of course nothing fell on the ground, but at that time nobody knew that the particles of the Leonid shower cannot reach the Earth's surface. Everybody was running. Everybody was shouting. That was the terror and chaos which seized the warriors.

The Meccans in the mountains most likely could not see the horizon. For them it meant that there, behind the mountains, in the west (or south west), by the sea, the burning bodies were falling on their enemies. Please take note of Figure 1 showing a picture created by an artist according to the description by an observer of the Leonid 'stars shower' of 1833 AD. When looking at this picture, we have the impression that the meteors are falling on the ground. Another example is the notes of an observer of the 'stars shower' of 1533 AD October 25th in Japan: 'A lot of stars were running in the firmament and falling down on the ground and sea' (Astapovich & Terenteva, 1966).

That meant that the Meccans were convinced that the burning objects were falling directly on their offenders, and it did not matter if some of these burning objects ceased to burn before reaching their target, because they were the same stones of 'baked clay' like those which had stricken the people of Lot to punish them for their sins. The stones occasionally falling from the sky were well known to Meccans. The most famous of them was the 'Black Stone'. They can see it almost every day. It is built into the north east wall of the Kaaba and it is highly respected by all Arabs. Thus the legend was born.

3 The second story

In the first story the time at which those events happened is known precisely. Therefore we tried to prove that the observed phenomenon was nothing but a 'stars shower' of the Leonid meteor shower. In the second story, assuming (from some arguments) that an observed phenomenon was the 'stars shower' of the Leonid meteor shower, we determine the time of the historical event.

'Let my people go!' – said Moses in the name of God. He asked the Pharaoh to let the Israelites go out to the desert for three days for praying, but the Pharaoh, who

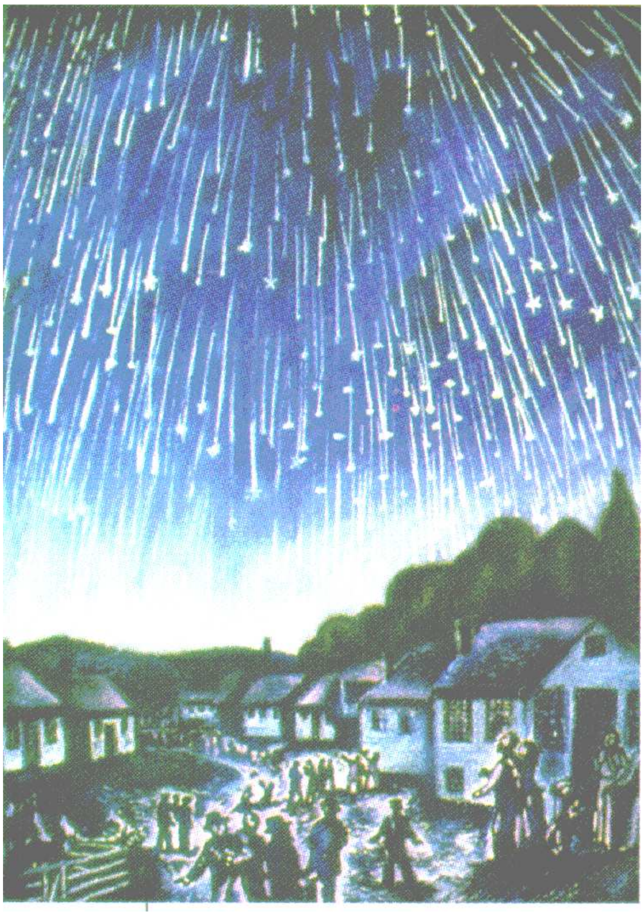

Figure 1 – An artwork illustrating the description of the Leonid meteor shower on the night of 1833 November 12/13, according to observations by Joseph Harvey Waggoner in Pennsylvania.

was very obstinate, refused to let them go. Therefore the legend says, God sent on Egypt what is known as 'the ten Egyptian plagues'.

> *Years later the king of Egypt died, ...*
> – ***Exodus 2–23*** (Good News Bible, 1976).

It is historically accepted that this concerns Pharaoh Ramses 2nd, ruling from 1292 till 1234 BC (Kosidovskij, 1966), and the return of Moses to Egypt during the rule of the Pharaoh Mernepta, the successor of Ramses 2nd. Mernepta spent the first years of his rule defending the western borders of Egypt from Libyan raids, and thereafter defending the eastern borders from the Indo-European tribes who had abandoned the Balkans not long before that time. And although Mernepta succeeded in defending his state, Egypt was weakened to the extent that it could not recover its previous power for a long time (Kosidovskij, 1966). That was perhaps the reason why the Israelites dared to begin their struggle for freedom. Moreover, it seems that the Israelites were enlisted to defend the borders, a task which had been forbidden to them before. The proof of this is the fact that the Israelites left Egypt with weapons in hand, and they could soon conduct some successful battles in Sinai (Kosidovskij, 1966).

It is absurd to think that Moses might have come back to Egypt at the time when Indo-European troops had hardly passed his native village in the land of Midian where he lived, and the war was still in progress at the frontier nearby. It is likely that he had waited till the remains of the Indo-European tribes returned back, and he might have learned the news about the situation in Egypt from them, and that the Israelites were allowed to participate in defending the country. Therefore it is logical to consider that some years had passed between the death of Ramses 2nd and Moses's return to Egypt. We think that that happened between 1228 and 1224 BC.

Now let us review the so called 'Plagues of Egypt'. Moses (or God) sent on Egypt ten 'plagues' in turn. We shall study the first seven of them (Good News Bible, 1976):

Book of Exodus

7–20 *... Aaron raised his stick and struck the surface of the river, and all the water in it turned into blood ...*

8–6 *... the frogs came out and covered the land.*

8–17 *... all the dust in Egypt was turned into gnats, which covered the people and animals ...*

8–24 *The Lord sent great swarms of flies into the king's palace ...*

9–6 *... all the animals of the Egyptians died, ...*

9–10 *... they produced boils that became open sores on the people and the animals.*

9–23 *... the Lord sent thunder and hail, and lightning struck the ground.*

It is well known since long ago, that the first six 'plagues' were common events in Egypt during the period of the Nile's flood. Therefore we shall use them only to determine the sequence of those events.

The Nile's flood in Egypt reaches its maximum on September 10–15. It is a fact that during the flood's period the water in the Nile contains about 15% silt, and for this reason it gets red-brown. After September 15th the water's level begins to fall, leaving behind pools and swamps filled with frogspawn, mosquitoes, midges and flies. The Quran plainly tells that the Plagues started at the time of floods. In chapter 7, 'The Elevated Places' – 'Sura Al Aaraf':

فارسلنا عليهم الطوفان والجراد والقمل والضفادع والدم ايات مفصلات

7.133 Fa 'arsalnaa 'alay-hi-muṭ-ṭuufaana wal-jaraada wal-qummala wad-dafaadi-'a wad-dama 'aayaatim-mufaṣ-ṣalaat.

7.133 *Therefore We sent upon them widespread death, and the locusts and the lice and the frog and the blood, clear signs; ...*

Here Shakir (Quran) used the attribute 'widespread death' so as to skip the translation of the Arabic word 'tawafan'. This word was translated by Krachkovski (Quran, 1986) as 'потоп' – deluge, while Soblukov in his so called 'Kazanski Quran' used the Russian word 'наводнение' – inundation. Nevertheless, it is clear that the Quran verse begins the story of the Plagues of Egypt with the water's flood.

We might have neglected that secondary information in the Quran. But there are two circumstances which oblige us to take this information seriously.
First – the number of the Plagues. Their number in the Quran is half their number in Exodus. It is not logical to cut by half the number of Plagues and at the same time introduce a new one – the flood. There is not a word about that in Exodus.
Second – In chapter 10, 'Jonah' – 'Sura Unis' (Quran) it says:

فاليوم ننجيك ببدنك لتكون لمن خلفك اية

10.92 Fal-yaw - ma nunaj-jiika bi-badanika lita-kuuna liman khalfaka 'aayah;

10.92 *But We will this day deliver you with your body that you may be a sign to those after you, ...*

The legend tells that the sea water covered the Pharaoh and all his army when they were following the escaping Israelites, and they all died. Here the Quran says that the dead body of Pharaoh was saved by Allah as a lesson to future generations. This appeared to be historically true when in 1898 AD, in the Valley of Kings, among 14 mummies in a crypt lay the mummy of Mernepta (Kosidovskij, 1966).

These two facts mean that the Quran's record about the departure of the Israelites from Egypt refers to – earlier than Exodus – a source which was preserved by the Jewish communities in Arabia.

Let us resume the matter of the Plagues. As the climate at that time was more humid than now, obviously during rainy years the tsetse fly appeared sometimes even in north Egypt and caused the death of the animals. The 'sandfly' lays its eggs under human skin and causes severe wounds which can be cured only by burning with a red-hot rod. This fly, even now, appears in the rainy years in northern desert regions of the Sudan and causes something like the sixth Plague.

The eighth, ninth and tenth Plagues are beyond the scope of our interest as they happened after the events of interest to us. Moreover, there is nothing to discuss, because the locust and the sandstorms, Egyptian darkness, are ordinary phenomena in that region. As far as the death of the first born is concerned, I wonder why historians have not seen in that a revolt of the Israelites and their killing of the Egyptian first born. Why else had Moses ordered the Israelites to mark the doors of their houses with blood and stay indoors all night?

Now we come to the seventh Plague – the fall of hail, and review Exodus, chapter 9, verses 23, 24, 26, 27 and 28 (Good News Bible, 1976):

9–23 *Moses raised his stick towards the sky, and the Lord sent thunder and hail, and lightning struck the ground.*
9–24 *The Lord sent a heavy hailstorm, with lightning flashing to and fro.*
9–26 *The region of Goshen, where the Israelites lived, was the only place where there was no hail.*
9–27 *The king sent for Moses and Aaron and said,*
9–28 *'Pray to the Lord! We have had enough of this thunder and hail!'*

I would like to draw your attention to some points:

Hail in Egypt! Hail everywhere! The only place where there was no hail was Goshen where the Israelites lived! Hail, not for some minutes or even hours, but almost for two days – the Lord stopped the hail only the next day after Pharaoh's promise to let the Israelites go!

Moreover, it is said here (9–23) that 'lightning struck'. In the Russian Bible version (The Holy Bible, 1968) in this place we read the words 'fire spread' (in the original 'и огонь разливался по земле' which can be literally translated as 'fire was flooding over the earth'). As the English Bible version which we used is a 'modern translation in everyday English', we trust the Russian version more, and consider that there is nothing about 'lightning' in the original. In 9–24, for 'lightning flashing to and fro', we take the Russian version – 'and fire amongst the hail' (in the original 'и огонь между градом').

So, what was that 'hail' and that 'fire spreading amongst the hail'?

We have to determine at what time of the year this phenomenon happened. Exodus 9–31 and 9–32 (Good News Bible, 1976):

9–31 *The flax and barley were ruined, because the barley was ripe, and the flax was budding.*
9–32 *But none of the wheat was ruined, because it ripens later.*

Anyone in Egypt will tell you that the 'hail fall' took place in late summer or early autumn when the summer crops ripen (barley and flax), while the winter crops were not sown yet. Here, we again take the Russian version which (in our translation to English) says, 'The wheat and spelt are not ruined because they were [sown] later.' (In the original 'А пшеница и полба не побиты потому что они были поздние.')

Hail falls in Egypt, although rarely, but in winter, in the rainy season, and not in summer when the barley and flax ripened and wheat was not yet sown. But I doubt that hail could have fallen for two days non-stop and accompanied by thunder and lightning.

In our opinion, the 'stars shower' of the Leonids was responsible for the phenomenon observed by the Israelites in 122x BC from far away, and was accepted by them as a plague on the Egyptians. Incidentally, Moses might have cheated the Pharaoh himself and convinced him that a catastrophe really happened, as the Capital of Egypt 'Ramases', where Pharaoh was at that time, was placed not far from Goshen, on the east side of the delta, and almost all the inhabited regions of the state lay to the west of Ramases. So when Mernepta was looking in the direction from the east to the west – the direction of the Leonid shower – it seemed to him that the stars, at the horizon, were falling on his people.

Table 4 – Correlation of the year of the 'hail's fall' with the period of recurrence of the heavy 'stars rain' of the Leonid meteor stream.

1966 – 1213 BC	$\bar{h}$ 33.11
1222 BC	$\bar{h}$ 33.21
1223 BC	$\bar{h}$ 33.22
1224 BC	$\bar{h}$ 33.23
1225 BC	$\bar{h}$ 33.24
1226 BC	$\bar{h}$ 33.25
1227 BC	$\bar{h}$ 33.26
1228 BC	$\bar{h}$ 33.27
1229 BC	$\bar{h}$ 33.28
1230 BC	$\bar{h}$ 33.29
1231 BC	$\bar{h}$ 33.30
1232 BC	$\bar{h}$ 33.31

Using Newton's formula (Astapovich & Terenteva 1966), we find that in the thirteenth century BC the maximum of the Leonid shower fell on August 15th. In Table 4 we can see that the year 1226 BC is in good correlation with $P = 33.25$ years. The year 1232 BC for $P = 33.31$ yr is too early for those events, while the year 1213 BC for $P = 33.11$ yr is too late.

In such a way we can offer a scheme for the chronology of those events:

- 1234 BC – the death of Ramses 2nd and the ascension of Mernepta;
- 1227 BC, before September – the return of Moses to Egypt;
- 1227 BC September – the Nile's water turns to 'blood';
- 1227 September to 1226 August – second to sixth 'plagues';
- 1226 BC August 14 to 16 – hail on Egypt ('stars shower' of the Leonid stream);
- 1226 August to 1225 April – locusts and 'Egyptian darkness';
- 1225 BC April – the death of the first born and the departure of the Israelites from Egypt.

4 Concluding remarks

In conclusion I would like to note the wonderful coincidence in these two stories:

- In both cases the phenomenon was observed from the east or north east and the enemy was in the west or south west (Figure 2).
- In both cases the observers watched from far away what seemed to them to be 'falling bodies' from the sky.

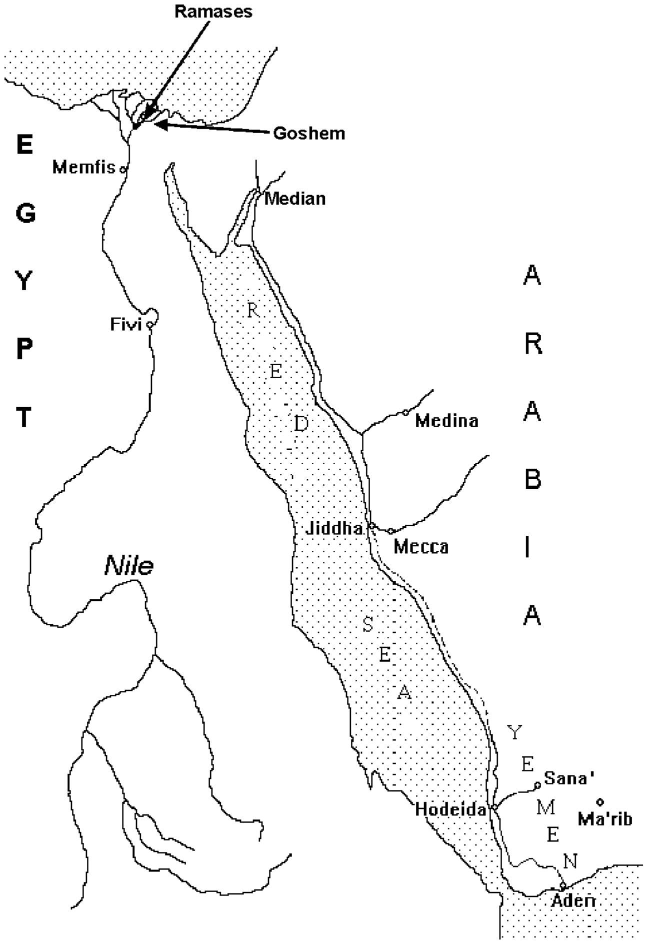

Figure 2 – Map of Egypt, Arabia and Yemen.

- In both cases only a few people could tell the rest about what 'really' happened to their enemies: in the first case Abdal Muttalib and some respectable Meccans, and in the second case Moses and his brother Aaron.
- In both cases the supposed year of the event correlates with the year of 'stars rain' of the Leonid stream (569 AD October 8th and 1226 BC August 15th).
- In both cases the maximum of the Leonid meteor shower came on the 12th day after the new moon (569 AD September 26th and 1226 BC August 3rd).
- In both cases the maximum of the Leonids came approximately at 11:00 Universal Time.

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Handling Editors: Galina O. Ryabova and David Asher
The Arabic text was produced by using *ArabTEX.*

Preliminary results

Results of the IMO Video Meteor Network — March 2009

Sirko Molau [1] *and Javor Kac* [2]

Cameras of the IMO Video Meteor Network covered all 31 nights in 2009 March. In more than 2100 hours of effective observing time, cameras recorded more than 4100 meteors. Two previously unknown shower candidates were detected in Hercules. The first shower candidate is active between March 1 and 9 while the second is active from March 10 to 16. Their velocities are respectively 44 and 36 km/s.

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1 Introduction

In many aspects, March was similar to February. The weather was only slightly better than in the month before, and we observed the same gradient between poor weather in the North and better weather in the South, even though the difference was less prominent this time. Once more, we managed to obtain more than 2 000 hours of effective observing time and 4 000 meteors – more than in the years before – mainly thanks to the automated cameras in Italy and Portugal (Figure 3 and Table 1).

With respect to meteor showers, March marks the rock bottom of the year. According to the IMO shower list (Rendtel & Arlt, 2008), only the delta Leonids are active in the first few days of the month. However, this shower was not detected in the recent meteor shower search. The gamma Normids of the southern skies are a similar case. Even though our video meteor database contains 15 000 meteors recorded in the southern hemisphere (Australia), they were not present in any of the recent analyses. In fact, even if we check the individual radiants at different solar longitudes, there is no sign whatsoever of the gamma Normids, which leaves serious doubts about the reality of this shower.

2 Two possible new meteor showers in Hercules

What does the 2008 analysis tell us about unknown showers in March? Two possible meteor shower candidates in Hercules that are not yet listed in the literature can be found in the first half of March. Eighty meteors were assigned to the first shower between March 1 and 9 (Figure 1, black). The radiant position on March 1 is rather uncertain, and is marked more faintly in Figure 1. The average velocity of this shower is 44 km/s, though there is some scatter from day to day because of the small number of meteors. The second shower candidate (Figure 1, grey) consists of 161 meteors between March 10 and 16. The first and last radiant positions are rather uncertain, and are marked more faintly in Figure 1. The average velocity was constant 36 km/s and, thus, slightly smaller than the velocity of the first shower.

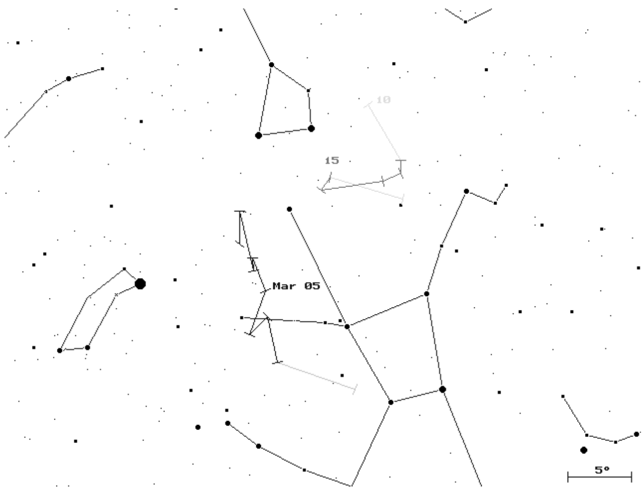

Figure 1 – Radiant positions of two possible meteor shower candidates in early March. Black line: 345 – f Herculids; grey line: 346 – x Herculids.

The highest activity of the first shower candidate occurs on March 7 at a solar longitude of 346 degrees (Figure 2, black), when the radiant is located at $\alpha = 268°$, $\delta = 41°$. The ZHR reaches a level of almost two. The shower was classified into the *Working list of meteor showers* at the Meteor Data Center of the IAU, under shower number 345 – FHE – f Herculids (IAU Meteor Data Center, 2009). The second shower reaches its highest ZHR of approximately one at a solar longitude of 352 degrees, when the radiant lies at $\alpha = 254°$, $\delta = 48°$ (Figure 2, grey). The only shower in the literature that lies close is the March Herculids, that Sekanina extracted from radar observations in 1968–69. The meteor shower velocity of these fits reasonably, but their radiant at $\alpha = 261°$, $\delta = 31.^{\circ}8$ lies more than 15 degrees south. Therefore, the shower was assigned a number 346 – XHE – x Herculids in the *Working list of meteor showers*.

It remains exciting as to whether these showers can be confirmed by other observers as well.

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NASA-ADS bibcode 2009JIMO...37...92M

Table 1 – Observers contributing to March 2009 data of the IMO Video Meteor Network.

Code	Name	Place	Camera	FOV	LM	Nights	Time (h)	Meteors
BRIBE	Brinkmann	Herne	HERMINE (0.8/6)	⊘ 55°	3 mag	17	72.7	177
CASFL	Castellani	Monte Baldo	BMH1 (0.8/6)	⊘ 55°	3 mag	21	144.9	205
			BMH2 (0.8/6)	⊘ 55°	3 mag	21	149.7	197
CRIST	Crivello	Valbrevenna	C3P8 (0.8/3.8)	⊘ 80°	3 mag	21	140.6	372
ELTMA	Eltri	Venezia	MET38 (0.8/3.8)	⊘ 80°	3 mag	3	14.7	34
GONRU	Goncalves	Tomar	TEMPLAR1 (0.8/6)	⊘ 55°	3 mag	23	186.3	451
			TEMPLAR2 (0.8/6)	⊘ 55°	3 mag	25	175.0	262
HERCA	Hergenrother	Tucson	SALSA (1.2/4)	⊘ 80°	3 mag	25	152.2	201
HINWO	Hinz	Brannenburg	AKM2 (0.85/25)	⊘ 32°	6 mag	6	18.7	34
KACJA	Kac	Kostanjevec	METKA (0.8/8)	⊘ 42°	4 mag	12	66.1	75
		Kamnik	REZIKA (0.8/6)	⊘ 55°	3 mag	10	52.5	135
			STEFKA (0.8/3.8)	⊘ 80°	3 mag	3	15.7	20
		Ljubljana	ORION1 (0.8/8)	⊘ 42°	4 mag	17	77.5	91
LUNRO	Lunsford	Chula Vista	BOCAM (1.4/50)	⊘ 60°	6 mag	12	85.4	177
MOLSI	Molau	Seysdorf	AVIS2 (1.4/50)	⊘ 60°	6 mag	8	35.8	282
			MINCAM1 (0.8/6)	⊘ 60°	3 mag	11	40.1	48
		Ketzür	REMO1 (0.8/3.8)	⊘ 80°	3 mag	20	59.7	112
			REMO2 (0.8/3.8)	⊘ 80°	3 mag	17	64.6	113
OCHPA	Ochner	Albiano	ALBIANO (1.2/4.5)	⊘ 68°	3 mag	21	137.6	260
PRZDA	Przewozny	Berlin	ARMEFA (0.8/6)	⊘ 55°	3 mag	15	60.2	130
SLAST	Slavec	Ljubljana	KAYAK1 (1.8/28)	⊘ 50°	4 mag	14	60.8	105
STOEN	Stomeo	Scorze	MIN38 (0.8/3.8)	⊘ 80°	3 mag	13	86.1	181
			SCO38 (0.8/3.8)	⊘ 80°	3 mag	8	49.2	202
STRJO	Strunk	Herford	MINCAM2 (0.8/6)	⊘ 55°	3 mag	16	36.6	58
			MINCAM3 (0.8/8)	⊘ 42°	4 mag	8	16.8	25
			MINCAM5 (0.8/6)	⊘ 55°	3 mag	11	49.1	106
YRJIL	Yrjölä	Kuusankoski	FINEXCAM (0.8/6)	⊘ 55°	3 mag	12	78.5	133
					Overall	31	2 126.8	4 186

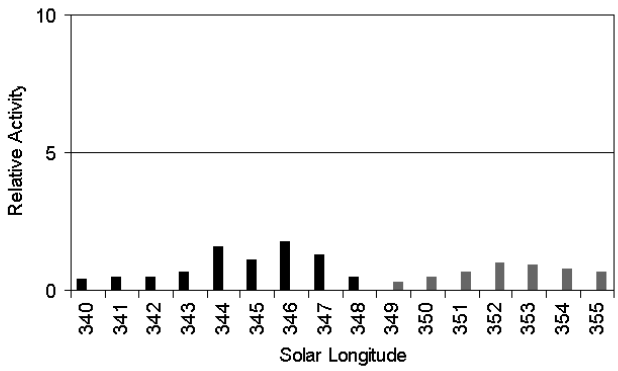

Figure 2 – Long-term activity profile of two possible meteor shower candidates in early March. Black: 345 – f Herculids; grey: 346 – x Herculids.

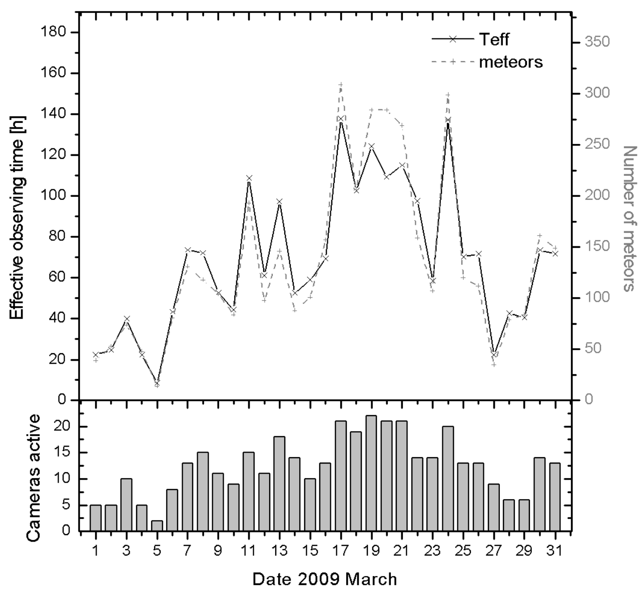

Figure 3 – Monthly summary for the effective observing time (solid black line), number of meteors (dashed grey line) and number of cameras active (bars) in 2009 March.

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Handling Editor: Javor Kac

Results of the IMO Video Meteor Network — April 2009

Sirko Molau [1] *and Javor Kac* [2]

The IMO Video Meteor Network cameras operated during all 30 nights of April 2009. More than 5600 meteors were recorded by 34 cameras during almost 2300 hours of effective observing time. The Lyrids reached their maximum on April 22/23 and were captured well by the cameras.

Received 2009 May 29

1 Introduction

In 2009 April, our more northern IMO Video Meteor Network observers were finally rewarded with fine observing conditions again. Most cameras obtained long observing series with only a few days missing. Almost all German observers managed to collect more than 20 observing nights, but in Southern Europe the weather was less optimal this observing period.

With more than 2 200 hours of effective observing time and 5 500 meteors observed, we once more achieved a new April record (Figure 1 and Table 1). This was not only thanks to the fine weather, but also a result of having 34 cameras in operation, which marks another record. Enrico Stomeo, for example, installed the new camera Min26. Utilizing a Computar 2.6-mm f/1.0 lens, Min26 is now the network camera with the single largest field of view (140 degrees diagonally). The biggest challenge for Stomeo and Min26 was measuring the reference stars such that there were no major position errors despite the image distortion. After a few fruitless trials, the third-order plate constants used by MetRec indeed proved able to describe such strong distortion sufficiently well, if only enough reference stars (> 80), distributed over the full field of view, are measured. Enrico Stomeo's work benefited from a new function in RefStars, which allows several sets of asynchronously recorded reference images to be grouped together in order to generate a fuller overall set of reference stars. This new feature also allows the same stars to be mesured at different times – the only requirement being that the full field of view is completely covered by measuring points.

We also welcomed two new observers in April: Mitja Govedič from Slovenia has taken over Orion2 from Javor Kac and provided first observations to the camera network. Antal Igaz also joins us as Hungarian observer. After a longer preparation phase, Antal is operating the two automatic stations Hubud and Huhod with Watec cameras and Computar 3.8-mm lenses. This is the start of a small camera network that should ultimately cover the full night sky over Hungary with double-station observations.

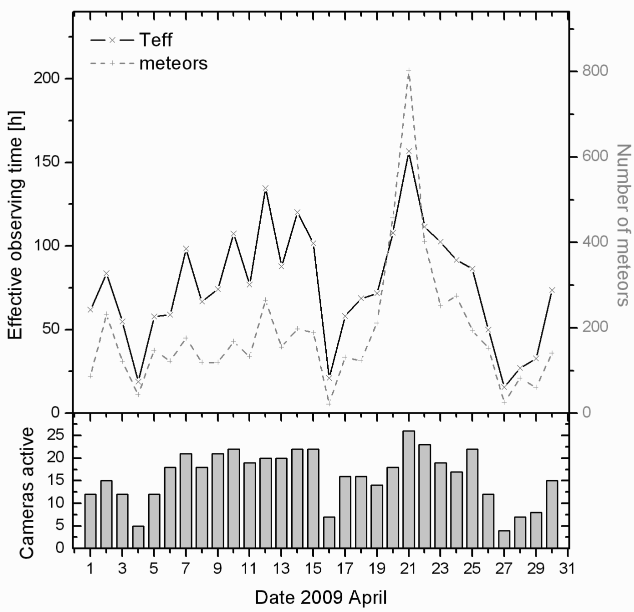

Figure 1 – Monthly summary for the effective observing time (solid black line), number of meteors (dashed gray line) and number of cameras active (bars) in 2009 April.

2 Lyrids

With respect to meteor showers, the Lyrids are the only rays of hope in the annual spring minimum. This year, their maximum was predicted for mid-day (UT) of April 22. So most European observers could only witness the ascending and the descending activity branch, which is why the total number of Lyrids was not so impressive. Only Bob Lunsford was able to capture the maximum well, under dark desert skies at the American west coast. He recorded a total of 29 Lyrids, and their hourly number was nearly constant between 9 and 12 UT.

Based on a total of 1 500 Lyrids, the 2008 analysis of the video meteor database yielded an interval of activity between April 19 and 25 (Molau, 2009), which falls somewhat short of the value given in the IMO meteor shower list (April 16–25) (Rendtel & Arlt, 2008). The absolute position of the video radiant matches well to the value from literature, but the direction of the radiant drift is slightly different (Figure 2). The Lyrids' velocity was determined to 46 km/s, which is smaller than the value given in the IMO Handbook (49 km/s), but matches well the figure given by IAU (47.1 km/s) (IAU Meteor Data Center, 2009).

According to the network's video data, the Lyrids reach their peak activity on April 22/23 at about 32°.5 solar longitude. The peak rate lies between 10 and 15

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NASA-ADS bibcode 2009JIMO...37...94M

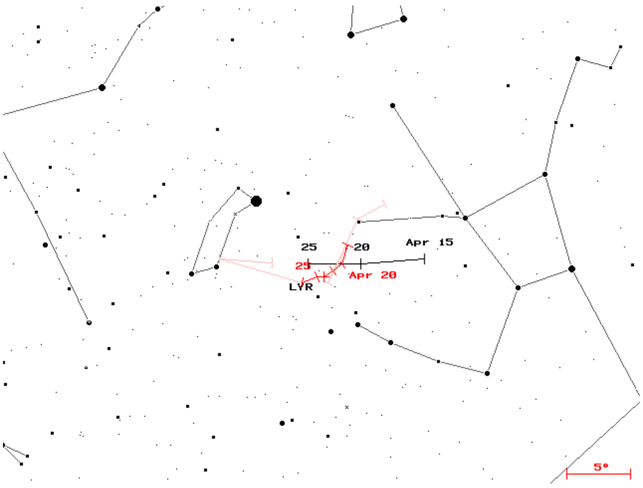

Figure 2 – Radiant position of the Lyrids from data of the IMO Video Meteor Database. Black line denotes the radiant drift of the Lyrids as given in the IMO Handbook.

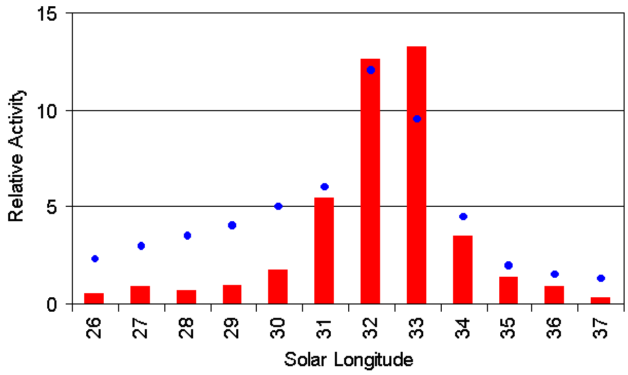

Figure 3 – Long-term activity profile of the Lyrids. Dots present the ZHR profile obtained from visual data.

per hour – but note that two days prior to, and two days after the maximum, the meteor rate is already below two (Figure 3). According to the IMO Handbook, the maximum obtained from visual data occurs at $32\overset{\circ}{.}3$, which confirms the video result nicely. Only the ascending activity branch shows a larger deviation. Similar to the data for the Quadrantids, the visual ZHR is here clearly above the video rate. This difference in rates of recorded activity plausibly stems from human expectations: observers, excited as they await the only large meteor shower of the spring, may perhaps be a bit too generous in assigning activity numbers for this meteor shower.

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Handling Editor: Javor Kac

Table 1 – Observers contributing to April 2009 data of the IMO Video Meteor Network.

Code	Name	Place	Camera	FOV	LM	Nights	Time (h)	Meteors
BRIBE	Brinkmann	Herne	HERMINE (0.8/6)	⊘ 55°	3 mag	22	88.0	205
CASFL	Castellani	Monte Baldo	BMH1 (0.8/6)	⊘ 55°	3 mag	15	51.5	66
			BMH2 (0.8/6)	⊘ 55°	3 mag	13	57.7	85
CRIST	Crivello	Valbrevenna	C3P8 (0.8/3.8)	⊘ 80°	3 mag	18	79.2	189
GONRU	Goncalves	Tomar	TEMPLAR1 (0.8/6)	⊘ 55°	3 mag	12	75.8	225
			TEMPLAR2 (0.8/6)	⊘ 55°	3 mag	13	70.4	154
GOVMI	Govedič	Središče ob Dravi	ORION2 (0.8/8)	⊘ 42°	4 mag	2	10.2	43
HERCA	Hergenrother	Tucson	SALSA (1.2/4)	⊘ 80°	3 mag	26	135.8	192
HINWO	Hinz	Brannenburg	AKM2 (0.85/25)	⊘ 32°	6 mag	17	84.3	165
IGAAN	IGAZ	Budapest	HUBUD (0.8/3.8)	⊘ 80°	3 mag	6	36.3	72
		Hódmező-vásárhely	HUHOD (0.8/3.8)	⊘ 80°	3 mag	7	35.9	54
JOBKL	Jobse	Oostkapelle	BETSY2 (1.2/85	⊘ 25°	7 mag	4	24.2	116
KACJA	Kac	Kostanjevec	METKA (0.8/8)	⊘ 42°	4 mag	14	62.7	72
		Ljubljana	ORION1 (0.8/8)	⊘ 42°	4 mag	15	52.4	70
		Kamnik	REZIKA (0.8/6)	⊘ 55°	3 mag	14	95.4	247
			STEFKA (0.8/3.8)	⊘ 80°	3 mag	5	13.8	22
KOSDE	Koschny	Noord-wijkerhout	TEC1 (1.4/12)	⊘ 30°	4 mag	10	36.4	41
LUNRO	Lunsford	Chula Vista	BOCAM (1.4/50)	⊘ 60°	6 mag	11	57.2	245
MOLSI	Molau	Seysdorf	AVIS2 (1.4/50)	⊘ 60°	6 mag	12	72.2	656
			MINCAM1 (0.8/6)	⊘ 60°	3 mag	23	96.3	171
		Ketzür	REMO1 (0.8/3.8)	⊘ 80°	3 mag	28	152.5	270
			REMO2 (0.8/3.8)	⊘ 80°	3 mag	26	157.5	398
OCHPA	Ochner	Albiano	ALBIANO (1.2/4.5)	⊘ 68°	3 mag	19	53.9	85
PRZDA	Przewozny	Berlin	ARMEFA (0.8/6)	⊘ 55°	3 mag	22	145.0	287
SLAST	Slavec	Ljubljana	KAYAK1 (1.8/28)	⊘ 50°	4 mag	8	24.6	34
STOEN	Stomeo	Scorze	MIN26 (1.0/2.6)	⊘ 120°	2 mag	11	43.4	61
			MIN38 (0.8/3.8)	⊘ 80°	3 mag	17	99.7	255
			SCO38 (0.8/3.8)	⊘ 80°	3 mag	18	90.7	308
STORO	Stork	Kunžak	KUN1 (1.4/50)	⊘ 55°	6 mag	2	13.3	195
		Ondřejov	ONDN1 (1.4/50)	⊘ 55°	6 mag	2	13.6	173
STRJO	Strunk	Herford	MINCAM2 (0.8/6)	⊘ 55°	3 mag	20	58.1	82
			MINCAM3 (0.8/8)	⊘ 42°	4 mag	11	28.3	42
			MINCAM5 (0.8/6)	⊘ 55°	3 mag	21	81.6	166
YRJIL	Yrjölä	Kuusankoski	FINEXCAM (0.8/6)	⊘ 55°	3 mag	19	81.7	162
					Overall	30	2 278.9	5 608

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Video meteors from Spain

These meteors were captured by Orlando Benítez Sánchez from Las Palmas de Gran Canaria, Spain using TIMES5 video camera. The system consists of Watec902-H camera and Computar 6-mm f/0.8 lens with a $70^\circ \times 50^\circ$ FOV. Date and time of meteor appearance is shown on each image.