Meteor Film Recording with Digital Film Cameras with large CMOS Sensors

Peter C. Slansky[1]

In this article the author combines his professional know-how about cameras for film and television production with his amateur astronomy activities. Professional digital film cameras with high sensitivity are still quite rare in astronomy. One reason for this may be their costs of up to 20 000 € and more (camera body only). In the interim, however,consumer photo cameras with film mode and very high sensitivity have come to the market for about 2 000 €. In addition, ultra-high sensitive professional film cameras, that are very interesting for meteor observation, have been introduced to the market. The particular benefits of digital film cameras with large CMOS sensors, including photo cameras with film recording function, for meteor recording are presented by three examples: a 2014 Camelopardalid, shot with a Canon EOS C 300, an exploding 2014 Aurigid, shot with a Sony α7S, and the 2016 Perseids, shot with a Canon ME20F-SH. All three cameras use large CMOS sensors; “large” meaning Super-35 mm, the classic 35 mm film format (24 × 13.5 mm, similar to APS-C size), or full format (36 × 24 mm), the classic 135 photo camera format. Comparisons are made to the widely used cameras with small CCD sensors, such as Mintron or Watec; “small” meaning 1/2” (6.4 × 4.8 mm) or less. Additionally, special photographic image processing of meteor film recordings is discussed.

Received 2016 November 15

1 Introduction

A classic (still) meteor photo shows the meteor as a streak. All information about the background sky is summed up over the integration time; all information about the meteor is summed up over the time and space of its angular movement over the sky. Hence in a single photo a lot of information about the meteor is lost: about the angular velocity of the meteor head, the temporal development of brightness and color of the meteor head and about trains and wakes (One part of this information, the angular velocity for example, can be saved in a still photo by the use of a rotating shutter in front of the lens.).

To record and preserve temporal information, cinematographic recording is one solution. Typically this is done with video cameras at 30 or 25 frames per second, depending on the television system, or by cameras attached to a computer with various frame rates. The resulting short integration time of typically 1/25 s to 1/30 s still does not give a frozen image, as it might seem, because the optical image of the meteor moves over the pixel pattern of the sensor during the integration time of the camera. In most cases the effective exposure time is limited by the meteor movement and not by the integration time of the sensor – just as in meteor still photography.

Figure 1 – This Camelopardalid was recorded by the author on 2014 May 24, $01^h58^m08^s$ UTC, in Munich, Germany, with a Canon EOS C 300 digital film camera with a Zeiss Superspeed Distagon 1.2/18 mm. The camera was running with 25 fps, $t = 1/25$ s, at ISO 20 000 with open iris. North is right. The image is cropped from a composite of 106 film frames, integrated with a maximum function. In the result the meteor appears as a streak. This is similar to a still photo with 4.24 s integration time ($106 \times 1/25$ s). Due to this integration over time, a lot of information about the temporal brightness and color development of the meteor head and of trains and wakes is lost. Compare this to Figure 3.

2 Camera technology

In meteor cinematography video cameras are normally used with one small monochrome charge coupled device (CCD) sensor. The main advantage of a CCD sensor is its comparably high sensitivity. The main disadvantage is the limitation in size and resolution: the widely used Watec 902H2 uses a 1/2” CCD sensor with a size of 6.4 × 4.8 mm and a native pixel count of 752 × 582. In order to keep the photo electrical effect efficient, the width and the height of the light sensitive area of a single pixel should be at least 5 times to 10 times of the wavelength of the light: 2.5 to 5 μm (Note, that usually the light sensitive area of a single pixel is only about 50% of the overall pixel area.). For a long time, CCD sensors for professional television cameras could not be built larger than for full HD resolution 1920 × 1080 pixels. The reason is that they have to be read out from as many vertical shift registers as the horizontal

---

[1] Hochschule für Fernsehen und Film München (University for Television and Film Munich, Germany).
Email: `slansky@mnet-online.de`

IMO bibcode WGN-446-slansky-film
NASA-ADS bibcode 2016JIMO...44..190S

Table 1 – Overview of cameras tested by the author.

	Canon C 300[1]	Sony α7S[2]	Canon ME20F-SH[3]
Camera type	Professional digital film camera	Consumer photo camera with film recording function	Ultra-high sensitive professional digital film camera
Cooling	active, balanced	passive, unbalanced	active, balanced
Sensor type	Color CMOS	Color CMOS	Color CMOS
Sensor size	22.5 × 12.7 mm	35.6 × 23.8 mm	35.6 × 20 mm
Sensor resolution	3840 × 2160 pixel	4240 × 2832 pixel	1920 × 1080 pixel
Native pixel size	6.25 × 6.25 μm	8.4 × 8.4 μm	19 × 19 μm
Recording resolution	1920 × 1080 samples	1920 × 1080 samples[4]	1920 × 1080 samples
Signal sample size	12.5 × 12.5 μm	19 × 19 μm	19 × 19 μm
Oversampling	2×	2.2×	none
Max. sensitivity	ISO 20 000[5]	ISO 400 000	ISO 4 000 000
Internal recording data format	MPEG-2	XAVC S	external recording only
Max. data rate	50 MBit/s (internal recording)	50 MBit/s (internal recording)	depending on external recorder
Lens mount	Canon EOS-mount or PL-mount	Sony E-mount[6]	Canon EOS-mount
Price (body only)	~18 000 €[7]	~2 000 €	~19 000 €

[1] `http://www.canon.de/for_home/product_finder/digital_cinema/cinema_eos_cameras/eos_c300_pl/`

[2] `http://www.sony.de/electronics/wechselobjektivkameras/ilce-7s`

[3] `http://www.canon.de/for_home/product_finder/camcorders/multi-purpose-cameras/me20f-sh/`

[4] In film mode with internal recording; with external recorder max. 3840 × 2160 pixels at max. 30 fps possible.

[5] Sensitivity in 2014; after a firmware update in 2016 max. ISO 80 000.

[6] A lot of full format lenses of various manufacturers can be used via adapters.

[7] Price 2014; now Canon C 300 Mk II is on the market.

number of pixels into just one horizontal shift register at the bottom of the sensor, being the bottle-neck for the information distribution[a].

Complementary metal oxide semiconductor (CMOS) sensors do not have this limitation, because they have read out devices in every single pixel and a three-dimensional sensor structure for the (two-dimensional) sensor read out. In the last five years, technological progress has led to higher sensitivity and higher dynamic range. This makes such cameras more and more interesting for certain fields of astronomy, especially for meteor cinematography – in full color. In contrast with a professional broadcast camera, a digital film camera uses one large CMOS sensor with a Bayer pattern for RGB color detection instead of three small CCD sensors with an RGB optical beam splitter prism. The light distribution efficiency of a beam splitter prism system is about 90% of the incoming light. Compared with that, the Bayer filter matrix with light absorbing filter elements has an average light efficiency of about 30%. Nowadays, however, this disadvantage is more than compensated by the enormous increase of light sensitivity of the CMOS sensors themselves along with the implementation of highly efficient noise reduction algorithms into signal processing.

Most digital film cameras have CMOS sensors of the size of the classic 35 mm cine film cameras. “Super 35” means 24 mm × 13.5 mm at an image ratio of 16:9. This size is close to the APS-C format for digital photo cameras of about 22 × 12.5 mm. There are also full format cameras on the market with an image size of 36 mm × 20 mm (16:9), coming from the classic 135 photo format 36 × 24 mm.

Digital film cameras and digital photo cameras with film function have in common that film recording is done with a significant oversampling: Most digital film cameras use sensors with 1.5 times to 2 times more pixels horizontally and vertically than in the sampled signal. Oversampling does not mean binning: The real time down scaling is done by complex algorithms, comparable to advanced image processing software like Photoshop. The scaling ratio is not limited to integer numbers such as 2:1 or 3:1. The oversampling is also to compensate for the loss of resolution of a color sensor, compared with a monochrome sensor, caused by the Bayer mask[b]. It gives digital film cameras a smooth image without artifacts like aliasing or color aliasing. The oversampling ratio has to be taken for width and

---

[a] In the meantime professional broadcast cameras were introduced with ⅔” CCDs with native UHD resolution 3840 × 2160 pixels.

[b] In a color sensor with a Bayer mask half of the sensor pixels are filtered in Green, a quarter in Red and another quarter in Blue. To reconstruct all three primaries for every sample of the signal, the native signal from the sensor has to be “de-bayered”. For this, the information of two green sensor pixels, one red and one blue sensor pixel sensor are combined. This causes an average loss of resolution of the sampled signal compared to the native sensor resolution of 0.63×, horizontally and vertically. This loss can be compensated by an oversampling with 1.6 times (1/0.63×) more pixels horizontally and vertically.

height, so a 2:1 oversampling means four times more native pixels on the sensor than recorded samples in the signal. For example, the Canon EOS C 300 has a color CMOS sensor with a Bayer mask with a native resolution of 3840 × 2160 pixels. The native signal from the sensor is de-bayered and downscaled in real time, resulting in a full HD signal with 1920 × 1080 samples being recorded. That means an overall number of 2 200 000 samples[c] per image. Compared with still photography cameras with up to 30 Megapixels this may sound mediocre, but full HD resolution is five times the pixel count of standard definition video (SD) with 440 000 pixels per image, being provided by cameras like the Mintron MTV-12V6HC-EX or the Watec 910HX-RC (without oversampling).

All three cameras have UV/IR cut filters. In the Canon ME20F-SH it can be deactivated motorized. All three cameras run from 2 frames per second (with frame integration) up to 60 fps.

Professional digital film cameras and digital photo cameras with film mode offer another valuable advantage over conventional video cameras: a significant wider contrast range. The contrast transfer function can be adjusted manually or via a set of different gamma presets: All three cameras offer "cine gamma" (whilst naming it differently), giving a very flat contrast distribution characteristic[d].

3 Camelopardalid 2014 May 24, $01^h58^m08^s$ UTC, from Munich, Germany, shot with Canon EOS C 300

At the Munich University for Television and Film (HFF), several professional digital film cameras with large CMOS sensors are in use for the student films – but sometimes even the professor for film technology is allowed to borrow one of them.

Figures 1 and 3 are the results of my first film meteor recording with a professional digital film camera. Figure 3 was chosen for the cover of the *WGN, Journal of the IMO* 42:3 (2014) – a great honor for me, being an amateur astronomer. My scientific approach was a technological one: to test the possibilities of this type of camera for meteor recording and imaging.

The Camelopardalid sequence that I captured was shot with a Canon EOS C 300, equipped with a Zeiss Superspeed Cine Distagon 1.2/18 mm, in Full HD resolution 1920 × 1080 pixels at $F = 1.2$ and ISO 20 000 with 25 frames per second and $1/25$ s integration time. Hence every frame represents an interval of $1/25$ s or 40 ms. On my rooftop terrace in the Munich city center the camera was put onto a mounting. The motors remained switched off. The camera was pointed near the zenith, with Polaris and Vega in the picture. Recording was started shortly after midnight, then I went to bed. The resulting $2^1/2$ hours film sequence showed only one meteor: the bright Camelopardalid at $01^h58^m08^s$ UTC in Figures 1 and 3.

Figure 2 – The instrumentation for the Camelopardalid 2014 May 24, $01^h58^m08^s$ UTC, Figures 1 and 3 was a Canon EOS C 300 with a Zeiss Cine Superspeed Distagon 1.2/18mm on a Lichtenknecker M 100 B mounting on my rooftop terrace in the Munich city center, Germany.

The Camelopardalid flew almost North to South, so its track went nearly parallel to the long side of the 16:9 image (North is right in Figures 1 and 3). Peter Jenniskens and Jim Albers from the SETI institute, California[e], sliced narrow strips from the frames of my original film sequence and put them one under another to a compositing image. To this composite I added a numbering for each frame. From the first appearance of the meteor to its maximum brightness Jenniskens/ Albers took only every second frame, from the maximum brightness to the vanishing of the train they took every frame. This change of the vertical scale (the time scale) causes a "virtual knee".

In the following diagram, the image was numbered by me from frame to frame to show the exact timing. It starts with $t = 0$: The frame before the meteor is detected by the camera. The maximum brightness is at frame 27 ($t = 1.08$ s). Already, however, at frame 17 ($t = 0.68$ s) the meteor shows an orange train that keeps glowing for more than three seconds until frame 106[f]. The meteor itself gets darker from frame 27 until it vanishes at frame 75 ($t = 3$ s). As Peter Jenniskens describes, from frame 50 ($t = 2$ s) the meteor becomes slower, as can be seen by the curvature in the image. Unlike the "virtual knee", caused by the change of the vertical time scale, this is a real effect: The meteor heats up, breaks into very small pieces and slows down until it vanishes. In the meantime, the glowing train keeps visible for more than another second, until frame 106.

The brightest visible stars in the original film sequence are Vega (0.1 mag) and Deneb (1.3 mag), the

---

[c] In a signal the correct term for what is called "pixel" in common speech is "sample". Hardware devices like sensors or displays have pixels, signals have samples.

[d] A classic video camera usually is set up to a logarithmic contrast transfer function with gamma = 0.45, according to CCIR Recommendation 601 (SD) resp. ITU Recommendation 709 (HD). This results in a contrast range of max. 7 F-stops or 128:1 (Slansky & Möllering, 1993). Measurements by the author have approved a maximum contrast range for the Canon C 300 up to 11 F-stops and for the Sony α7S up to 13 F-stops.

[e] `http://meteor.seti.org`

[f] It was this orange train that attracted Peter Jenniskens' special interest

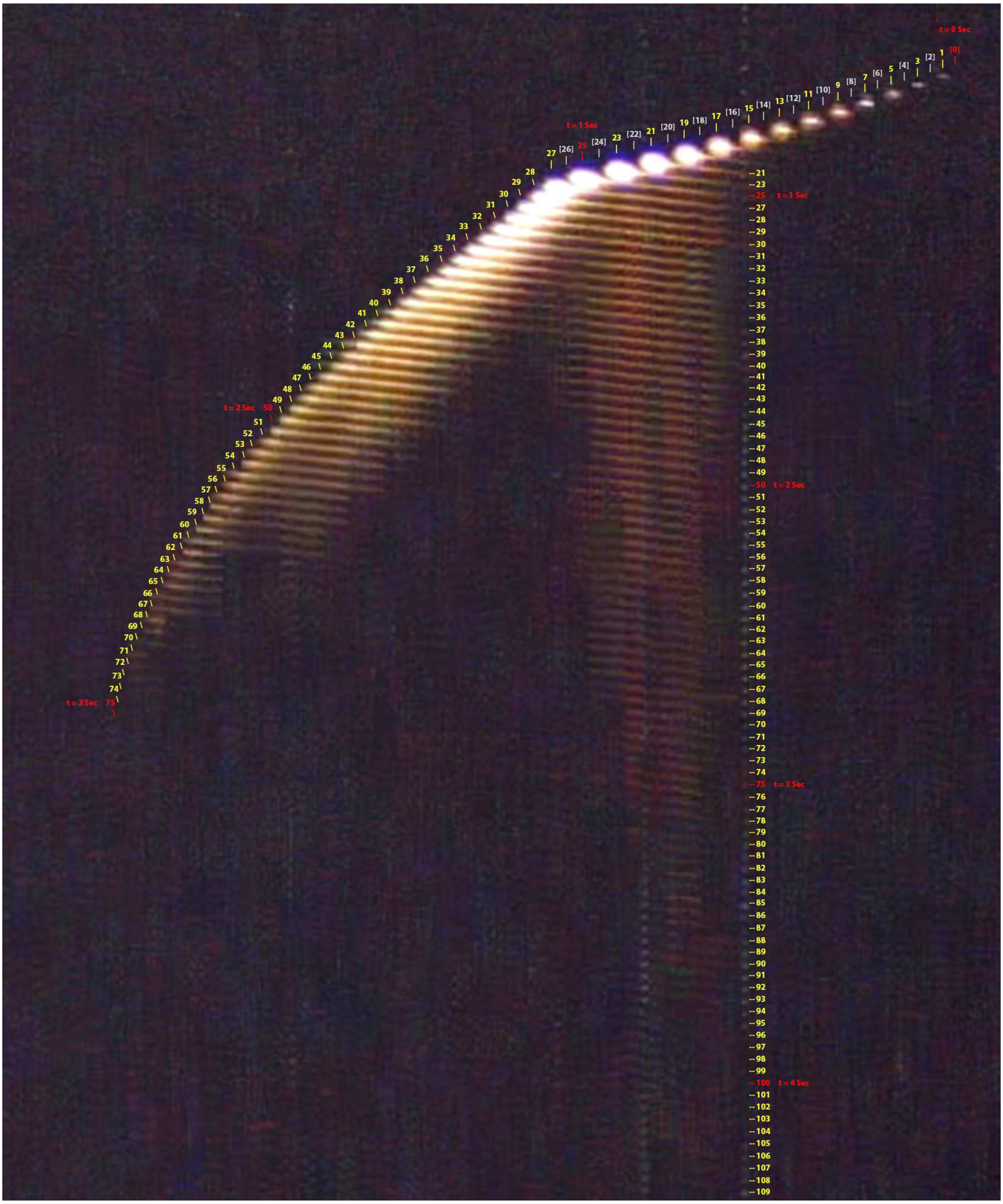

Figure 3 – Camelopardalid on 2014 May 24, $01^{\text{h}}58^{\text{m}}08^{\text{s}}$ UTC, from Munich, Germany, from same original film sequence as Figure 1, shot with a Canon EOS C 300 digital film camera with a Zeiss Superspeed Distagon 1.2/18mm. The sensor size is 22.5 × 12.7 mm. The camera was running with 25 fps, $t = 1/25$ s, at ISO 20 000 with open iris. North is right. The compositing was done by Peter Jenniskens and Jim Albers, SETI Institute, Los Angeles, USA (Jenniskens, 2014). It shows each film frame displaced by 5 pixels vertically, projected in such a way that the meteor moves from right to left. The vertical direction from top to bottom is the timeline. The numbering of each film frame (= 1/25 s; yellow) and of each film second (every 25th frame; red) was done by the author. The sequence starts with an interval of only every second film frame to be shown for the first second. The jumped frames are marked with white numbers in brackets. After one second the sequence continues with every film frame to be shown until the end at frame No. 109 ($t = 4.36$ s). Only because of this change of the scale of vertical timeline, there is a "virtual knee" in the curve at frame No. 26. From the top to the bottom this sequence shows the temporal development of the meteor frame by frame: the persistent emission and wake as well as the deceleration when the meteoroid breaks. Also, the temporal development of the meteor brightness can be estimated: The star slightly left from the vertical number column, marked in green, is χ Draconis (3.7 mag). Additional information is provided by the development of the colors of the meteor head, persistent train and wake. Compare this to Figure 1. The author offers this information to the scientific meteor community, leaving conclusions – for example brightness estimations – to the expert.

faintest are 24 Draconis (5.0 mag) and 30 Draconis (5.2 mag). Note, that the faintest stars can only be seen in the original film sequence running at 25 fps: In a single still frame resp. in Figure 3 they vanish in the image noise. This makes it difficult to prove the limiting star magnitude in a print copy. Modestly estimated, the limiting star magnitude of the film sequence can be assumed with mag 5.2. This is not very far from the (poor) sky darkness of the observation site in the center of Munich. In Figure 3 a star is visible (marked in green): χ Draconis, mag 3.7. Considering all these factors it would be possible to determine the magnitude of the meteor. For this further research has to be made.

The film sequence can be seen here: `http://slansky.userweb.mwn.de/bereiche/astronomie/meteore/camelopardalid_24-05-2014_ani_k.html`.

4 Exploding Aurigid 2014 September 1, $05^h44^m44^s$ UTC, from La Palma, Canary Island, shot with Sony α7S

With a maximum sensitivity up to ISO 400 000, the Sony α7S is by far the most light sensitive camera for photo and film mode in a price range of 2 000 € (body only) at the moment. It has a full format CMOS sensor 35.5 × 23.5 mm with a native resolution of 4240 × 2832 pixels and a native pixel size of 8.4 × 8.4 μm. In film mode the active sensor area is cropped to 35.5 × 20 mm (16:9). With internal film recording it is down sampled to full HD resolution of 1920 × 1080 pixels, with a sample size of 19 × 19 μm. Connected to an external data recorder via the micro HDMI 1.4 interface, film recording is possible up to UHD resolution 3840 × 2160 Pixels at max. 30 fps, depending on the recorder. The Sony E lens mount has a very short camera flange back distance, so it is possible to adapt nearly every full format lens to the α7S via third party adaptors.

One major disadvantage of the Sony α7S for meteor recording is that, being a consumer photo camera instead of a professional film camera, the maximum film recording time is limited to less than 30 minutes. This was implemented by the manufacturer due to toll regulations that provide a lower tax rate for consumer photo cameras than for professional film cameras. It can only be prevented by using an external recorder.

The exploding Aurigid fireball in Figure 4 was recorded on 2014 September 1 at $05^h44^m44^s$ UTC from my hotel balcony at La Palma, Canary Island, about 40 m above sea level. The Sony α7S was equipped with a Zeiss ZE Sonnar 2.8/35mm. The camera was put onto a tripod and pointed to North by Northwest. The film sequence was recorded with 25 fps with $t = 1/25$ s, ISO 200 000 and $F = 2.8$.

The frame by frame composite image Figure 4 (left) shows how the meteor enters the image field from right to left at frame No. 2 with a constant angular speed. The meteor head is strongly overexposed, but the following wake is not. At frame No. 7 the meteor head disintegrates completely in an abrupt explosion. A greenish train can be seen for about 1 s. The white afterglow of the explosion remains visible for more than 10 s, exceeding by far the range of this sequence analysis of 55 frames (= 2.2 s) until the bottom of Figure 4 (right). The changing of the colors of the train and the explosion cloud can be studied easily frame by frame.

The film sequence can be seen here: `http://slansky.userweb.mwn.de/bereiche/astronomie/meteore/aurigid_01-09-2014_ani_k.html`.

5 Perseids 2016 August 12/13 from Emberger Alm, Austria, shot with Canon ME20F-SH

In 2015 Canon presented an ultra-high sensitive professional film camera with a maximum sensitivity of ISO 4 000 000, the Canon ME20 F-SH. It has no internal recording nor a viewfinder nor a display, all needs to be attached externally. It has a full format CMOS sensor with a native resolution of full HD 1920 × 1080 Pixels, resulting in a pixel size of 19 × 19 μm, the biggest native pixel size on the market right now. Together with an advanced noise reduction system, this is the key to the extraordinary sensitivity. The sensitivity of the ME20 F-SH can be switched from 0 dB by gain steps of 3 dB. +6 dB mean an increase of one F-stop or a factor 2 for the ISO number, +3 dB means half an F-stop or factor 1.4. The maximum sensitivity of +75 dB is stated to be equivalent to ISO 4 000 000. For this goal, the manufacturer has sacrificed smoothening of the image by oversampling.

Unfortunately, the Canon ME20F-SH is out of reach for most amateur astronomers due to its price of 19 000 € (body only). The need for an external data recorder with a display and a separate power supply does not make the handling very comfortable. However, the ME20 has no recording time limit, unlike consumer cameras like the Sony α7S.

For the 2016 Perseids observing campaign, the author and Bernd Gährken, also from Munich, went to Emberger Alm in the southern Austrian Alpine Mountains at 1 740 m above sea level. Two Canon ME20F-SHs, equipped with Canon USM II 1.4/35 mm photo lenses, were provided by Canon Germany Ltd., Krefeld. These two cameras, together with two Sony α7S with 2.8/35 mm Zeiss lenses, were mounted on a Lichtenknecker M 100 B mounting. Two data recorders Ambient PIX 240i were connected to the Canon cameras. All cameras were pointed to Polaris, covering the same sky area simultaneously. The sensitivity was set up differently from camera to camera via ISO number and F-stop. This setup was chosen to compare the cameras on the same motive and for a direct measurement of the population index, the topic of another article yet to come.

Molau et al. (2014) have pointed out that the simple detection of faint stars in the image is not a very reliable criteria for the limiting star magnitude. But it does give a first draft. They tested a Mintron 12V6-EX against a Watec 910HX-RC: Under a mag 6.0 sky and with a 0.75/6 mm Panasonic lens the Mintron reached a limiting star magnitude 5.1 and the Watec mag 5.5. Many cameras of the IMO Video Meteor Network do not reach this magnitude.

Peter Jenniskens (2014) used Night Vision MX-9916/UV image intensifier tube cameras for the 2014 Camelopardalid campaign from an airplane at an altitude of 6 000 to 8 000 m, reporting a limiting star magnitude 6.9. With the Canon ME20F-SH, set to ISO 1 400 000, $F = 2.0$ and 25 fps, $t = {}^1/_{25}$ s, a limiting star magnitude was reached up to mag 8.6.

The star detection as well as the meteor detection was performed “manually” by playing back the original film sequences in real time on a computer monitor; no detection software was used. The image presented in Figure 7 was summed up from 100 film frames and cropped from the original full HD resolution.

On the first night, 2016 August 11 to 12, the cameras were running from 23^h09^m to 02^h01^m UTC. During these 2:52 hours the most sensitive Camera 1, a Canon ME20F-SH, recorded an overall of 266 meteors, among them 224 Perseids. On the second night, August 12 to 13, the cameras were running from 21^h35^m to 01^h21^m UTC. Despite some

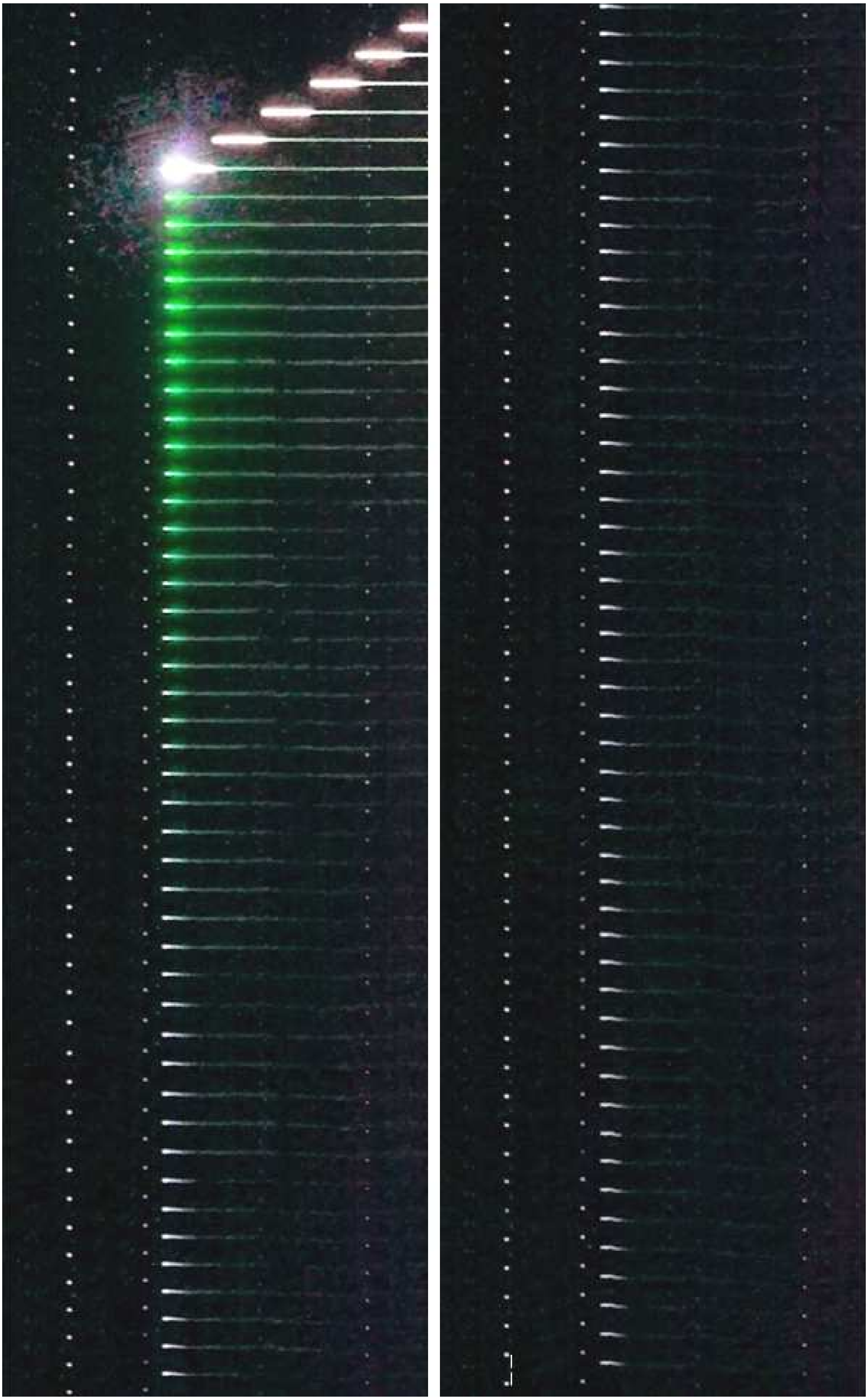

Figure 4 – Exploding Aurigid fireball on 2014 September 1, $05^{\rm h}44^{\rm m}44^{\rm s}$ UTC, from La Palma, Canary Island. The original film sequence was shot with a Sony α7S with a Zeiss ZE Sonnar 2.8/35 mm. The camera was on a tripod, pointing to North by Northwest. The film sequence was recorded with 25 fps with $t = 1/25$ s, ISO 200 000, $F = 2.8$.

Figure 5 – 45 Perseids 2016, composite image with maximum function. The star in the image center is Polaris, Ursa Minor is left. The original film sequence was shot with a Canon ME20F-SH with a Canon USM II 1.4/35 mm lens. It was recorded with 25 fps, $t = 1/25$ s and ISO 1 400 000 at $F = 2.0$.

Figure 6 – Instrumentation for the 2016 Perseids, Figures 5, 7 and 8. Two Canon ME20F-SH cameras and two Sony α7S were mounted on a Lichtenknecker M 100 B, with an image field rotating around the sky North Pole. The location is Emberger Alm in the Austrian Alpine Mountains, 1 760 m above sea level. On the bottom of the mounting (not in the picture) two data recorders were connected to the Canon ME20 cameras. Over all, ten AC power supplies were needed.

Figure 7 – Composite image of 100 film frames of the brightest Perseid on 2016 August 11/12, $01^{\rm h}29^{\rm m}33^{\rm s}$ UTC, from Emberger Alm (at the bottom right in Figures 5 and 8). Due to the average function of the compositing, the green train of the meteor is prominent while the bright overexposed meteor head is nearly invisible. Modestly estimated, stars down to mag 8.6 can be identified – also in the original film sequence when running at 25 fps.

clouds passing the field of view, in 3:43 hours an overall of 247 meteors were recorded by Camera 1, among them 163 Perseids. For the whole campaign with 6:35 hours recording time in two nights, this makes an overall of 513 meteors, among them 387 Perseids.

The original data amount of all four cameras was 740 GB, 240 GB for each Canon ME20 and 130 GB for each Sony α7S. Image processing and analysis are not yet finished.

Images and film sequences can be seen here: `http://slansky.userweb.mwn.de/bereiche/astronomie/meteore/perseiden_2016_01.html`.

6 Film image processing

As was explained earlier, a film sequence contains much more of the temporal information about a meteor than a still photo. A part of this information can be transformed back into a still image, for a printed article for example, by special image processing. For this, film editing software as well as astronomical imagery software is needed.

To show just one example, two composite images of the brightest 45 Perseids of the first night from the same source image sequence will be compared: Figure 5 and Figure 8.

The data recorder Ambient PIX 240i recorded in the professional video codec ProRes in 8 Bit per channel. The ProRes sequences were imported into a professional film editing software, ADOBE PREMIERE CC 2015. For each of the 45 meteors, a sequence of 100 film frames (= 4 s) was exported in TIF 8 Bit RGB. These TIF sequences were the key to the astronomical imagery in FITSWORK 4.47 and the compositing in PHOTOSHOP CC 2015.

Figure 5 shows the composite of the 45 brightest 2016 Perseids from August 11, $23^{\rm h}10^{\rm m}10^{\rm s}$ UTC to August 12, $01^{\rm h}59^{\rm m}02^{\rm s}$ UTC. The emphasis was laid on the bright meteor heads by a composite of 45 composites: Each meteor sequence of 100 frames was composed in FITSWORK 4.47 with the maximum function. The maximum function transfers the maximum brightness value of all 100 frames for each pixel into the resulting composite. Due to the very high sensitivity of the camera of ISO 1 400 000, $F = 2.0$, $t = 1/25$ s, most of the meteor heads are strongly overexposed. This causes a noticeable blooming. In a second step the 45 maximum composites were combined in PHOTOSHOP to a 45-layer composite and combined again with the maximum function. The resulting image Figure 5 shows the bright tracks of each meteor head. With this method of image compositing, much of the original image noise is visible. The colors of the meteors are nearly invisible because of the overexposure of the meteor heads. This composite does however offer an initial estimate for the magnitude of the meteors.

Figure 8 shows the same 45 Perseids, but with the compositions in the first step being made via the average function. As a result of this, the persisting trains of each meteor are displayed in their typical green color. Because at on every pixel the bright meteor head is apparent only for one frame from 100, its value is lowly weighted by the average function, compared to the sky background. The trains remain for at least one second, up to several seconds, so the averaging of 100 frames results in a strong emphasis on them.

Figure 8 – Composite image of 45 Perseids 2016; same sequence as Figure 5, but composite made with an average function. By this, the green persistent trains are dominant and the bright meteor heads are pushed into the background.

The comparison between these two composites from the same original source shows the various possibilities of meteor film recording in full HD resolution and color. More research about these possibilities seems to be valuable.

Acknowledgements

I wish to thank Barbara Arriens from Canon Germany Ltd., Krefeld, for providing me with two brand new ME20F-SH cameras with lenses for the 2016 Perseid campaign. I thank the University of Television and Film Munich for providing me with the cameras for the 2014 Camelopardalids and the 2014 La Palma fireball. I also wish to acknowledge considerable cooperation with Bernd Gährken and his preparations and the weather prediction for the 2016 Perseid campaign and for his help with the analysis. Also, I want to thank Sirko Molau, who gave his advice in the systematic of the 2016 Perseid campaign. Very important input has also been given by Matthias Knülle, especially to the choice of the lenses. I thank Peter Jenniskens for his valuable response to the 2014 Camelopardalid, my initial meteor film recording, and for his analysis. Last but not least, I thank Daniel Fischer for his initiative to forward the information about my Camelopardalid film sequence to the scientific community, finding Peter Jenniskens.

References

Jenniskens P. (2014). “Camelopardalids (IAU#451) from comet 209P/LINEAR”. *WGN, Journal of the IMO*, **42:3**, 98–105.

Molau S., Kac J., Crivello S., Stomeo E., Barentsen G., Goncalves R., and Igaz A. (2014). “Results of the IMO Video Meteor Network – March 2014”. *WGN, Journal of the IMO*, **42:3**, 120–124.

Slansky P. C. and Möllering D. (1993). *Handbuch der Professionellen Videoaufnahme*. Edition Filmwerkstatt, Essen.

Handling Editor: Felix Bettonvil

Perseids on 2016 August 12/13 from Emberger Alm, Austria