QHY (5L-II-M) CCD camera for video meteor observation

Matej Korec

Maximilian Hell Observatory & Planetarium
korec@planetarium.sk

A new digital camera and lens has been tested for video meteor observing. A Tamron M13VG308 lens combined with a QHY 5L-II-M digital camera proved to be the best combination. Test observations have shown this to be superior to the best analog Watec 902H2 Ultimate camera.

1 Introduction

I am a member of the Central European Meteor Observation Network (CEMeNt). Its basic activity is multi station video meteor observation. The recorded data is primary used for computing atmospheric and heliocentric meteoroid trajectories. For bolides in particular we always try to harvest as much additional information as possible, including primary mass, ablation, deceleration, fragmentations and also, if there is any real chance of a fall, the parameters and trajectories of all fragments, including the dark flight part. Using this data we try to find meteorites and have been successful on a few occasions. We have also recently started some projects for faint meteors and spectroscopic observations. All data are stored in the EDMOND database and after computation the information is combined with data from other networks and is used by various research programs.

2 Current situation

The primary network equipment is now based on cheap and relatively sensitive analog cameras. Some popular configurations (camera + lens) are displayed in *Figure 1*. They include very well validated TV technologies which were recently applied in the security segment which uses an analog process to output the data. Over 10 years ago this was necessary for the transfer and recording of large amounts of information because digital technologies weren't powerful enough for this purpose. However, in the last few years faster computers have become available and the additional processing that converts the analog output to digital has introduced some rather unfortunate limitations such as:

- First, a large portion of the almost unfilterable noise causes a degradation of the SNR factor.
- The resolution is limited to 720 x 576 for PAL or to 640 x 480 for the NTSC standard.
- The frame-rate (exposure time) is strictly set to 25fps (0.04s) for PAL and 30fps (0.03s) for NTSC.
- A particularly nasty issue is the interlaced video signal, which is degrading the measurement precision.
- Photometric measurements are only possible in 8-bit depth.
- The dynamic range is relatively low, e.g. max 50db (usually 36db), therefore very bright meteor or bolide explosions are not measurable.
- Last but not least, any usable TV grabbers are hard to buy; many of them are no longer manufactured and there is a similar issue regarding sufficiently fast (f/1 or better) aspherical, precisely IR corrected lenses (especially for the most used 1/2 inch chips).

CCTV Cameras specifications			
Name	Watec 902 H2 Ultimate	KPF 131 HR	VE 6047 EF
Sensor	1/2" Sony Ex-View HAD	1/3" Sony Super HAD II	1/3" Sony Super HAD CCD
Resolution (px)	752 x 582 (720x576)	582 x 500 (720x576)	960 x 582 (720x576)
Resolution (TVL)	570	500	700
Sensitivity	0.0001 lx F=1.4 QE76%	0.002 lx BW, F=1.2	0.001 lx BW, F=1.2
S/N	> 50 dB (> 36 db)	> 50 dB	> 50 dB
Price	350 Eur + Lens 150 Eur	80 Eur + Lens 30 Eur	60 Eur + Lens 30 Eur

CCTV Lens specifications			
Name	Computar HG3808FCS	Tokina M2311	Fujinon YV2.7x2.9LR4D
Properties	1/2" CS F=0.8 ASP IR focal length 3.8 mm	1/3" CS F=0.98 ASP IR varifocal 3 - 8.2 mm	1/3" CS F=0.98 ASP IR varifocal 3 - 8.2 mm

Figure 1 – Overview of currently popular configurations.

Therefore I and a few other colleagues from CEMeNt (Roman Piffl in particular) have tried to find a suitable digital camera for meteor observations. I first considered the new generation of DSLR with a sufficient sensitive chip and RAW HDMI video output. I have tested the Canon EOS 6D, ISO 102400 (Q.E. equivalent 56%) with a Fisheye lens, Canon EF 15mm f/2.8 (180 degrees diagonally, pretty 6mm effective diameter), with a PCI-e HDMI input card which was recommended by Mr. Sonataco (author of the UFO HD capturing and analyzing software). The lens is no longer manufactured, but it is still available on the second hand market and an alternative exists from Zeiss which is still being produced. The applied color masking and the noise producing high gain decrease the predicted theoretical sensitivity, but the results were still usable. However, the main disadvantage of this set up is the price. The cost of many thousands of Euros makes it unviable as a replacement for most of the cheap analog cameras that are currently used.

Tamron M13VG308

Imager Size			1/3
Mount Type			CS
Focal Length			3.0 - 8mm
Aperture Range			1.0 - 360
Angle of View (Horizontal x Vertical)	1/3	Wide	92.5° x 68.2°
		Tele	35.4° x 26.5°
	1/4	Wide	68.2° x 50.6°
		Tele	26.5° x 19.9°
Focusing Range			0.3m - ∞
Operation		Focus	Manual with Lock
		Zoom	Manual with Lock
		Iris	DC Auto Iris
Filter Size			-
Back Focus(in air)			Wide 8.31 - Tele 14.92 mm
Operating Voltage			Open 4.0 V Close 0.7 V
Weight			75g
Operating Temperature			-20 °C - +60 °C

Figure 2 – Details of the recommended Tamron lens.

SPECIFICATION TABLE

CMOS Sensor	MT9M034
Optical Format	1/3-inch
Effective Area	4.83mm (H)x3.63mm(V)
Array Format	1280×960
Pixel Size	3.75µm×3.75µm
Readout Type	Progressive Scan
Shutter	Electronic Rolling Shutter (ERS)
Exposure Time	20µs-10min
BIN and BIN Type	No
Q.E.	Color: 52%@ Blue, 62%@Green,58%@Red Mono: 74%
Frame Rate(MAX)	30 FPS@1280×960; 44 FPS@1024×768 75 FPS@800×600;106 FPS@640×480 200 FPS@320×240
Color/Mono	Color/Mono
ADC	On-chip, 14 Bit (8 Bit Output)
Data Rate	24-74.5 MHz
Dynamic Range	> 115dB
Telescope Interface	1.25-Inch Eyepiece Size
IR Cut Filter	22mm, Can be Removed to Replace with other Filters (Color Sensor Only)
Intercept	10.4mm
Weight(Body Only)	45g (without Location Ring)
Camera Size	Diameter=31.6mm; Length=52mm
Power Supply Mode	USB-Power
Power Consumption	0.64W
Guide Port	Build in Optic Isolated Guide Port RJ11 6pin1
USB Interface	USB2.0 High Speed Interface
Standard Fittings	Camera Body, Pacing Ring,USB Cable, Guide Cable
Optional Fittings	CS Interface, Super Radiator, Tripod Tube, Extension Tube

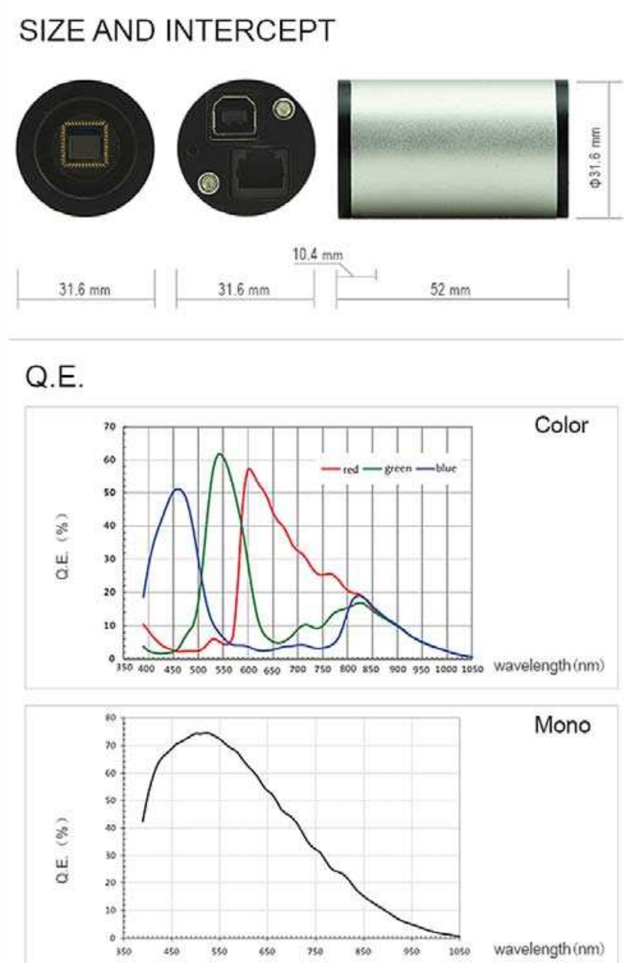

Figure 3 – Detailed parameters for camera QHY 5L-II-M.

3 The Tamron M13VG308 as lens

We subsequently carried out testing using dozens of cameras and lenses in cooperation with our colleagues from the Polish video meteor network. The conclusion was that there exist only one truly megapixel aspherical f/1 (or better) lens, which is still being manufactured, for a 1/3 inch chip camera with a wide field of view. It is the *Tamron M13VG308*. Many other lenses claim similar parameters, but the images from these lenses were unusable. In some cases the lens wasn't even good enough for an analog camera. The specification of the recommended Tamron lens is shown in *Figure 2*.

I recommend the version with a DC Iris. Digital cameras usually do not have an iris port, but you can connect the pins from the DC connector to a 4–5V power unit with a clock programmed to open the iris at the start in the evening and to close it at the end of the session in the morning, so as to protect the chip from direct sunlight. Alternatively, it is possible to attach a DC connector to the serial port (RS232) pins and write a simple script to open and to close the iris. On a recent computer, a USB to serial converter can be used. A closed iris is not fully closed, but is just shielded to f/360. In such a configuration the chip is sufficiently protected from direct sunlight.

It is still possible, however to observe daytime bolides. In order to do so, it is necessary to run a macro that will set camera parameters differently for day and night work. The gain, in particular, must be set at a lower value for use during daytime with another setting for the night. The task scheduler can be used to run macros or scripts at the appropriate times. Sonataco`s UFO Capture HD program also offers the possibility of being used for daytime observations.

4 The QHY 5L-II-M as camera

An even more complicated issue occurred regarding the camera. After investigating many options, the ZVO ASI 120 seemed to be almost as sensitive as analog cameras. It also has a WDM driver to function with the capturing software (UFO HD) that is being used. The theoretic parameters and the "indoor" tests were good, but attempts to observe meteors in the real sky failed completely.

I then borrowed a QHY 5L-II-M. At first I was skeptical about it as it has the same chip as the ASI 120 but the other electronics, and the A/D converter and software in particular, were much better. Hence, this camera not only produced much better results on the real sky than did the ASI 120, but performed even better than the most sensitive analog Watec 902H2U! The QE of both cameras is almost the same, but the QHY has a more than 2 times better SNR and, hence no noise from the a/d conversion is added. In other words, you can observe stars (and other events) one magnitude fainter with the digital QHY 5L-II-M than with the analog Watec 902H2U when using identical optics. The QHY5-II series are cheap multifunctional cameras usable for auto guiding, solar and planetary observations, as electronic finders and also for simple deep sky observations. Support from the ASCOM driver is standard and allows exposures of up to 10 minutes and it has a low dark noise. The camera body is like a 1.25 inch eyepiece and hence the telescope mass can cool the camera to an ambient temperature without the need for any active cooling. The fast L-M version with a high Q.E. of 74% without color mask is as great for occultations as it is for video meteor observations. The detailed parameters for this camera are shown in *Figure 3*.

Most important for meteor observations is the high resolution of 1280 x 960 with a fast frame-rate of 30fps, 115db dynamic range (twice better than the best analog systems) and a high Q.E. with a maximum in the visual range, but with good values also in the near infrared. The bit depth, mentioned as 14bit is also of interest and is only usable at higher exposure times, while the 12bit can be used at 15fps. This can improve the photometry of meteors significantly, when the work on the 12 bit color-space support in the capture program (UFO Capture HD2) has been finished by Sonataco (the author is working on this function).

The QHY 5-II camera can be bought in 2 different equipment versions. The complete version is shown in *Figure 4*, but for meteor observation the simpler and cheaper one is sufficient. Installation of the camera body only requires a camera tripod and a CS mount reduction ring. The Tamron M13VG308 lens requires a CS mount reduction ring as well as a 1mm thin spacing ring in order to focus with the widest field of view! Make sure that you have a free USB 2.0 bus when the camera functions at a fast speed mode (more than 15 fps) as the camera will need the full speed of this interface. A USB 3.0 is even better if this is available.

Figure 4 – The complete version of the QHY 5-II camera.

5 Some real observing test results

The astrometrical precision measured from test observations with the same field of view size as is used by most analog observation set-ups, approximately 80° diagonally, is ±15 arc sec. For those who work with UFO software the ddeg value is 0.005 (analog systems have maximum 0.04). The precision is significantly better! In practice it is best to use the QHY5L-II-M with Tamron M13VG308 with a maximal field of view of 120° diagonal on the chip. In this case, the precision would not be so good, but would still be much better than on analog systems.

We expect that the hyperbolic trajectories that can be incorrectly computed for very fast meteors, when using analog cameras, will disappear, or at least be reduced to a more acceptable number. The photometric precision at 8bit is also very good. The chip sensitivity is linear over practically the full dynamic range. The S/N for the average 2.5 mag. events is better than 50 and for faint 5 mag. events better than 8. During the first double station observing test near Perseid maximum, my colleague Jakub Koukal used a spectroscopic grid of 10 A/pix on his camera. Using a grid decreases the camera sensitivity significantly, but it is still able to record spectra from standard meteors, not just from very bright ones. He was lucky and recorded a spectrum for a sufficiently bright meteor. The resolution was three times better than for spectroscopic observations on analog systems and the sensitivity was also much better. Results from the first analysis of this event can be seen in *Figures 5, 8 and 9*. The data was only corrected for the sensitivity differences in the observing equipment.

Figure 5 – Perseid spectrum recorded by Jakub Koukal.

In *Figures 6 and 7* you can see the images from the digital QHY 5L-II-M camera and from the best analog camera, Watec 902H2U for comparison. The video frame-rate was the same, 25fps (0.04s), as were the number of captured frames and all the operations applied to the raw data to convert this into a more presentable format. The records were captured only a few minutes apart, under the same conditions and of course from the same place. The effective digital camera lens diameter was 3 mm whereas a high quality Tokina lens with 3.6 mm diameter and 6.5mm focal length was used on the analog camera. The Watec has a much smaller field of view. It is a little bit smaller compared to a standard analog system. The measurement precision is indeed better in this case. The standard analog camera field of view (*Figure 7*) is marked as a rectangle in the digital image (*Figure 6*).

Usually, when something seems to be almost perfect, at least one problem must appear. The QHY 5L-II-M camera works fine with a basic driver and the original program EZ Planetary developed by the manufacturer. However, for video meteor observation it is necessary to use a special capturing program. UFO Capture HD 2 which needs the WDM driver, is the only useable program. QHYCCD also created this type of driver for this. However, this primarily uses the RGB color-space, which is not supported in the UFO software package. The camera manufacturer has built a new version of the WDM driver with another predefined color-space. Unfortunately the data conversion is not completely correct and so the output produced is not as good as that from the basic driver. The SNR is a little bit worse. I am negotiating with QHYCCD and it seems that this problem will be solved in the coming weeks. The camera can be used for video meteor observing with its present settings. You can see this in *Figures 5 and 6*.

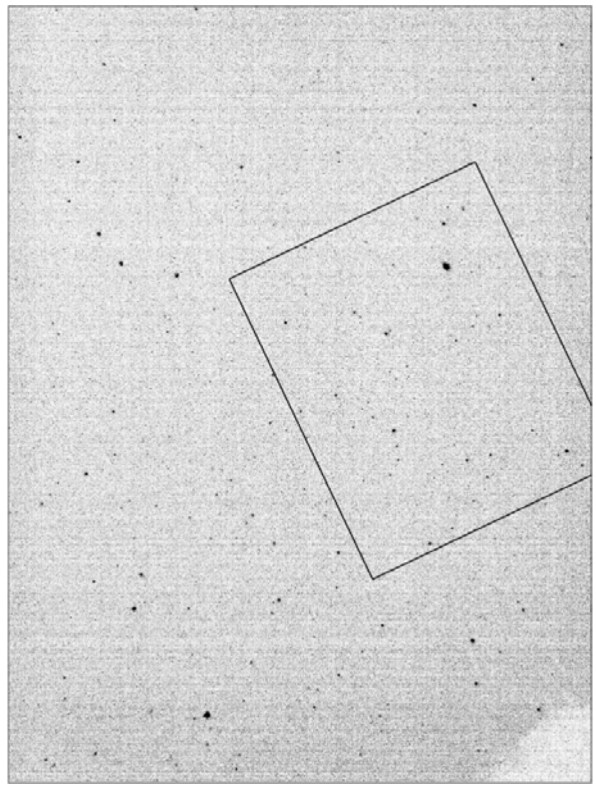

Figure 6 – A digital QHY 5L-II-M camera image.

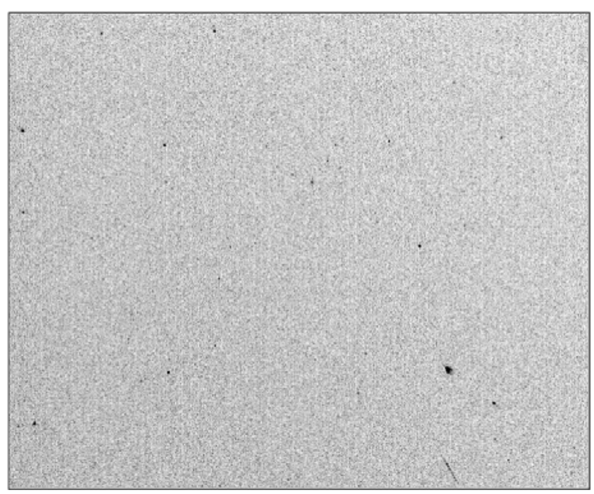

Figure 7 – An analog Watec 902H2U camera image to compare with *Figure 6*.

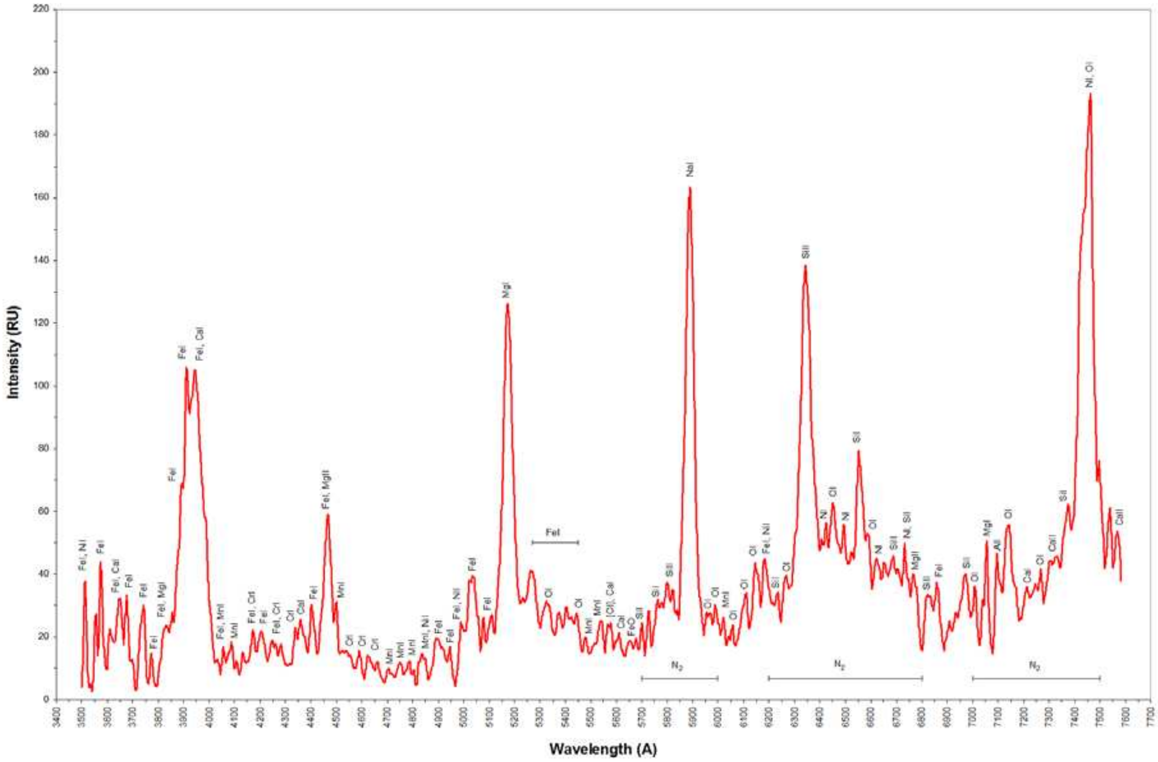

Figure 8 – Perseid spectrum recorded by Jakub Koukal.

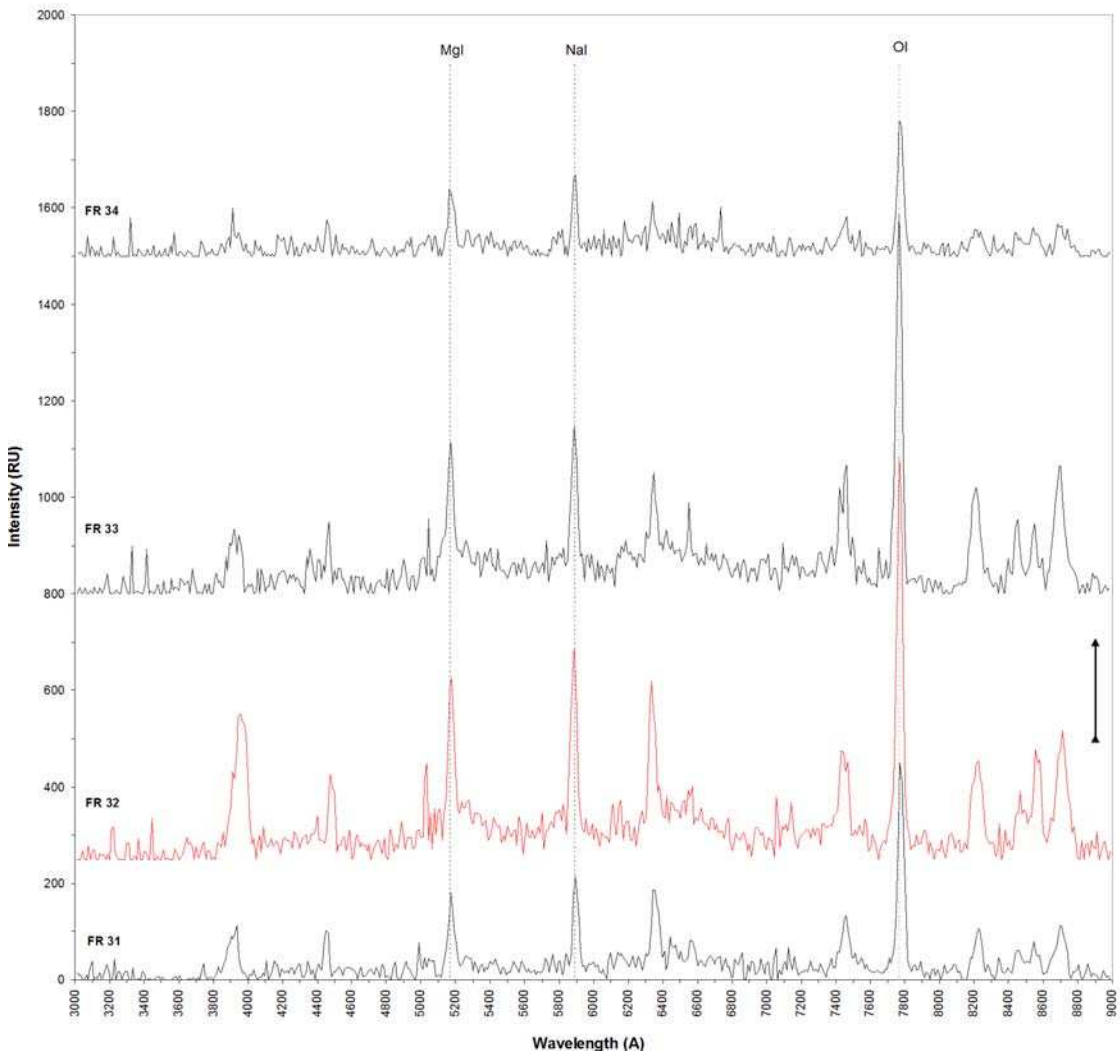

Figure 9 – Evolution of the Perseid spectrum recorded by Jakub Koukal.