# French Meteor Network for High Precision Orbits of Meteoroids

P. Atreya • J. Vaubaillon • F. Colas • S. Bouley • B. Gaillard • I. Sauli • M.-K. Kwon

**Abstract** There is a lack of precise meteoroids orbit from video observations as most of the meteor stations use off-the-shelf CCD cameras. Few meteoroids orbit with precise semi-major axis are available using film photographic method. Precise orbits are necessary to compute the dust flux in the Earth's vicinity, and to estimate the ejection time of the meteoroids accurately by comparing them with the theoretical evolution model. We investigate the use of large CCD sensors to observe multi-station meteors and to compute precise orbit of these meteoroids. An ideal spatial and temporal resolution to get an accuracy to those similar of photographic plates are discussed. Various problems faced due to the use of large CCD, such as increasing the spatial and the temporal resolution at the same time and computational problems in finding the meteor position are illustrated.

**Keywords** meteor · CCD · observation

## 1 Introduction

Meteor astronomy has implemented video techniques for all-night observations in addition to visual and photographic during the past decade. The IMO Video Meteor Network [1], Polish Fireball Network [2], Spanish Meteor Network [3], Dutch Meteor Society [4] and Czech Meteor Network [5] are few of the meteor networks actively operating in Europe. Detection and analysis software such as Metrec, Meteorscan and UFOcapture eases the tedious setup and encourages professional and amateur astronomers alike to set up meteor stations.

These networks have thrived from off-the-shelf video cameras and lenses. One of the major drawbacks from these configurations is the astrometric quality of data acquired. The typical cameras used (Watec, Mintron etc.) with 640 × 480 pixels, along with medium angled lens (~50°), have spatial resolution of 0.08°/pixel. This corresponds to a resolution of 140 m if the meteor is at 100 km distance from the camera. This causes a large uncertainty in velocity, and thereafter, in the semi-major axis of the meteoroids. For example, a typical meteor with velocity of 39.9 km/s corresponds to semi major axis of 5 AU, whereas, velocity of 40.0 km/s corresponds to 10 AU, a change of 0.1km/s in velocity corresponding to 5 AU in this particular case [6]. Semi-major axis is very sensitive to velocity component of the meteoroids, and thus we need 10 order of magnitude better spatial resolution than most of these off-the-shelf cameras for precise meteor velocity and semi-major axis.

The need for more precise orbital elements of meteoroids is imminent for modeler's. Figure 1 shows the node of different trails (1817-1913 AD) of Draconid stream for the year 2011. Only with high resolution observation and precise semi major axis, it is possible to identify the exact trail that will cause the outburst on 8$^{th}$ October, 2011. Similarly, the 2009 Leonids outbursts were predicted to occur due to

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trails from 1533 AD and 1536 AD [7], whose radiants differ by 0.9°. But the observations made from current instruments were not able to identify the exact trail from which the outburst occurred. So there is need for better accuracy, which can be obtained by higher temporal and spatial resolutions.

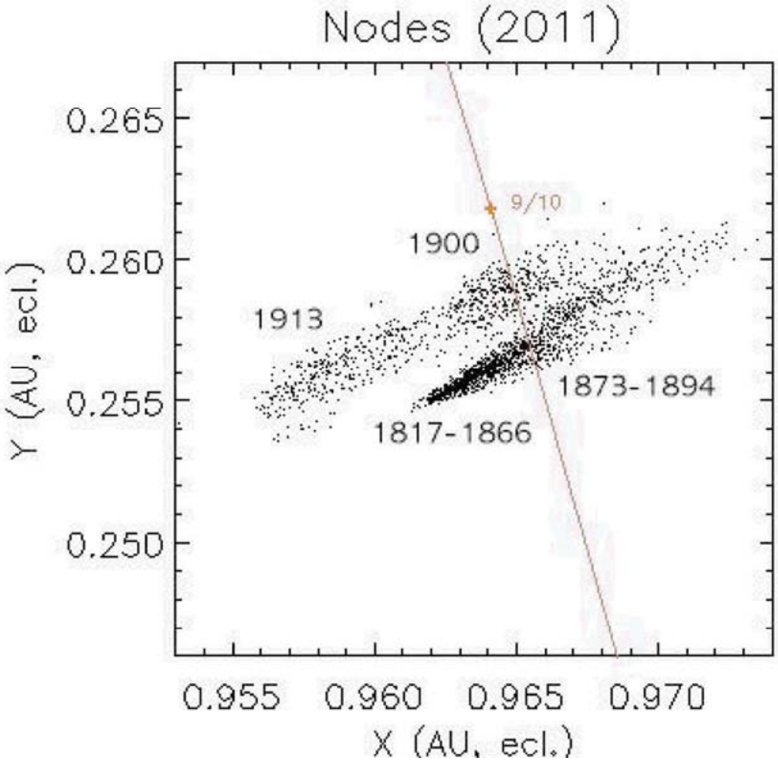


**Figure 1**. The node of Draconids meteoroid stream with trails from 1817 – 1913 AD for the 2011 outburst.

There are generally two ways to increase the spatial resolution of the camera system, i.e. to use a large CCD and to use a narrow lens. However, only increasing the spatial resolution is not sufficient for obtaining precise velocity. A simple simulation was performed to identify the spread of meteor in a single image for a fixed high resolution of 0.01°/pixel for various frame rates. Figure 2 shows the length of a meteor (in pixels) for different temporal resolution for slow (angular speed of 10°/s) and fast meteors (angular speed of 30°/s).

For the typical video frame rate of 25–30 fps the slow meteor will be spread out across 40 pixels, whereas the fast meteor will be spread more than 100 pixels. Thus it will be difficult to compute the position of meteor within 1 pixel accuracy as its spread across too many pixels. When the frame rate is increased to 100 fps, the meteor is spread across only 10–30 pixels. Thus increasing frame rate is essential if spatial resolution is increased to estimate the meteor position accurately in the images. Due to this reason, even if narrow lens are used with small CCDs with video frame rate, it will have computational disadvantages.

There are also several disadvantages of using large CCDs. The time to read a single frame in a CCD is inversely proportional to the size of the CCD. Table 1 shows the frame rate of different size of CCDs from JAI camera company. Only the smallest CCD have temporal resolution of 100 or better, which is preferred for good spatial resolution. An external rotating shutter can be used to provide good temporal resolution.

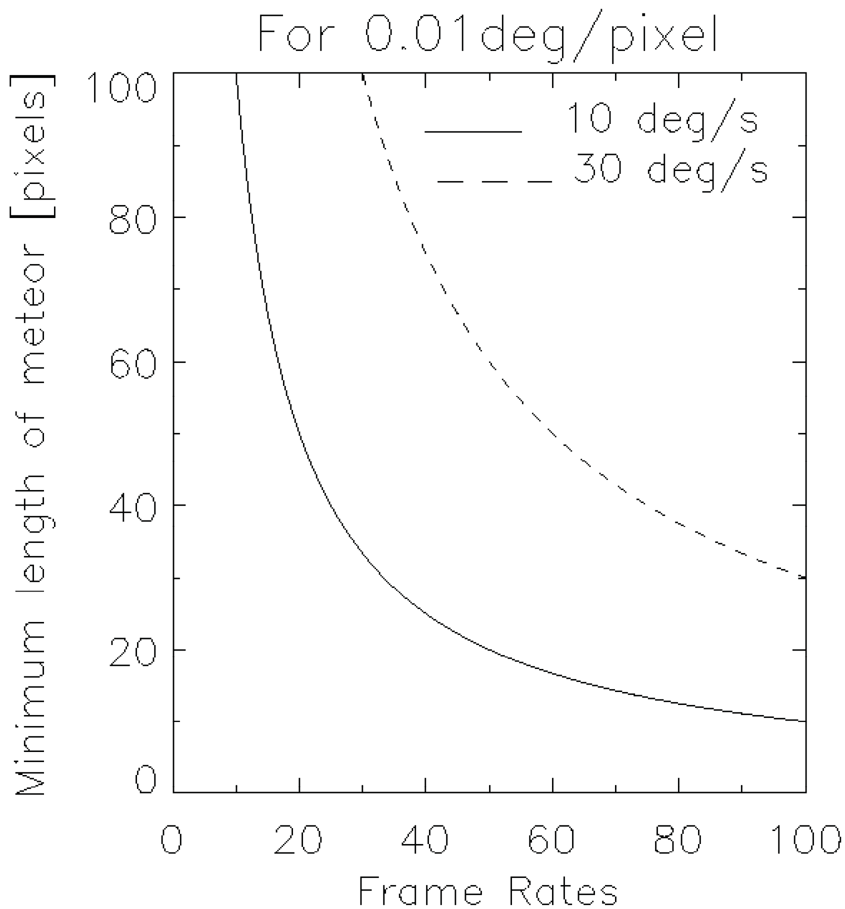


**Figure 2.** The length of a meteor for different temporal resolution for two typical meteor speed. The spatial resolution of set to 0.01 deg/pixel

**Table 1.** The frame rate of different sizes of CCDs.

| Camera ID | Size of CCD [Pixels] | Max Frame Rate |
|---|---|---|
| RM-6740CL | 648 × 484 | 200 |
| CM-140GE | 1392 × 1040 | 31 |
| CM-200GE | 1628 × 1236 | 25 |
| BM-500GE | 2456 × 2048 | 15 |
| AM-1600GE-F | 4872 × 3248 | 3 |

## 2 Lheritier Camera

Lheritier, a French camera and system vision company, has developed an interline progressive scan camera LH11000. It uses Kodak Kai 11002 sensor with 4032 × 2688 effective pixels of 9 µm size. The readout noise is ~30 $e^-$, with gain of 0−30 DB. The images are saved in 16 bit format. It takes 149 ms to read a single image, and the frame rate is 6.7 fps. The minimum and maximum shutter speeds are 0.8 ms and 52428 ms respectively. This camera was tested for military and aviation environment and can withstand −10°C to 50°C and humidity of 100% non condensing.

Figure 3 shows the modification of CCD readout method to mimic electronic shutter system. The top part of the figure shows the basic procedure of CCD system. The signal denotes the exposure duration (10 ms), and all the images are stored separately. This is not ideal because of the "dead time" of 149 ms after every image. A modification to a CCD system was made by introducing a "break" period (10 ms) which means that during this period the CCD is closed as shown in the bottom section of the figure. The images are stacked onto the CCD (N = 50 times), and read out only once. This method not only decreases the dead time of the camera, but due to stacking of the images, causes an effect very similar to the external rotating mechanical shutter. The "signal", "break" and the total exposure duration can be modified to suit fast and slow meteors. This method was possible as Lheritier company developed a way to "close" the CCD completely, which is used as "break" duration. This also implies that there is no upper limit to the size of CCD that can be used for the detection of meteors due to low temporal resolution. The dead time of reading a single image can be reduced by making longer exposures.

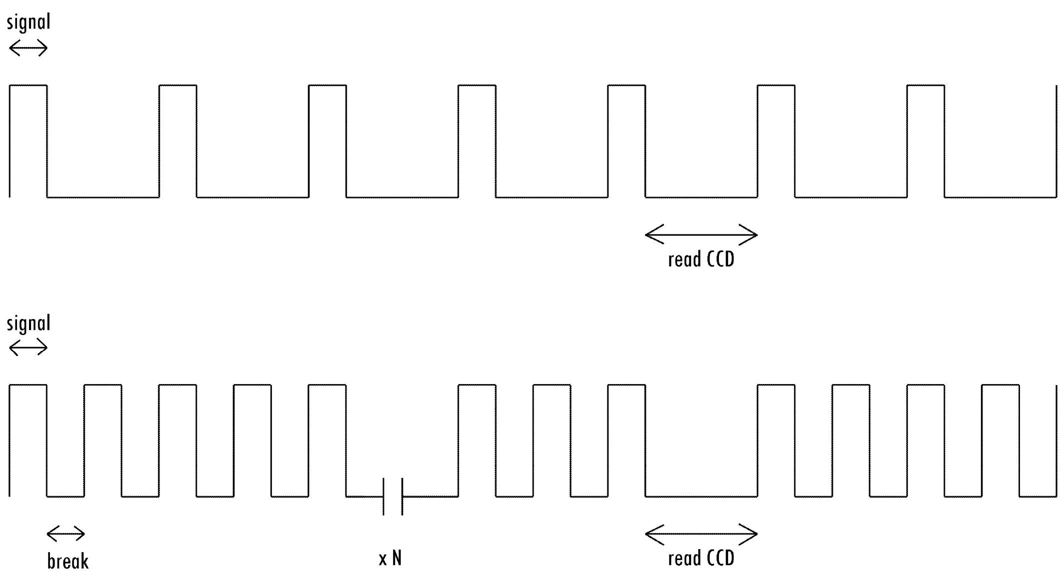


**Figure 3.** Modification of basic CCD readout method to mimic electronic shutter system.

Figure 4 shows an example of meteor detected (raw image) with LH11000 camera, modified shutter system and Nikon 85 mm F1.4 lens (FOV 28° × 18°). The meteor was captured during Lyrid observation campaign on 22nd April, 2010 at 00:56:50 UT from Observatory of Haute Provence (OHP), France. The spatial resolution is ~0.007° or ~25". The signal and break duration was set to 10 ms and the total exposure of the image was 1 second (N = 50 loops).

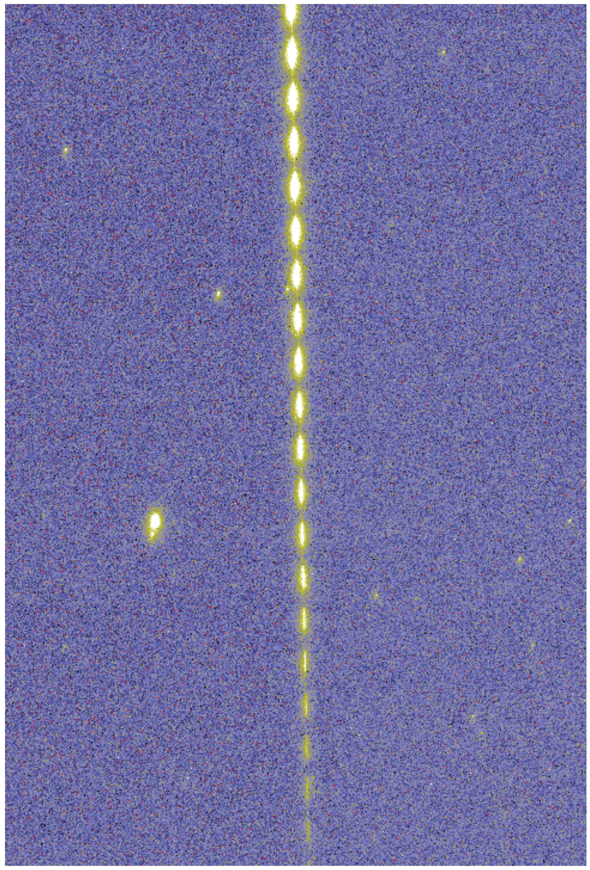

**Figure 4.** Example of a meteor (raw image) with 10 ms signal, 10 ms break and total exposure of 1 seconds.

The intensity plot for few breaks is shown in Figure 5. The distance between the peaks are ~40 pixels. With the spatial and temporal resolution of 0.007°/pixel and 10 ms respectively, the angular velocity is ~28°/s, which agrees with those of general meteors. Precise position and velocity can be computed by fitting different types of curves in the reduced data. Figure 4 and smoothness of the intensity curve of Figure 5 proves that this new method of electronic shutter works.

## 3 French Meteor Network

The first video meteor network will be started in France under PoDeT-MET project. The primary aim of this network is to get high precision orbits of meteoroids. The Lh11000 camera is equipped with Cannon 50mm F1.2 lens (FOV 40° x 27°) and have spatial resolution of 0.01° which is ~8 times higher than the numerous off-the-shelf systems. This corresponds to 17.4m resolution if the observed meteor is at a distance of 100 km. The first dedicated triple station network will be set up in south of France during 2010−2011. The first station will be set up at Pic du midi Observatory, at the height of 3000m. The other two stations will be set ~100 km further away. An all sky camera will also be installed to compliment the high precision cameras. The network will be expanded to other areas of France in future.

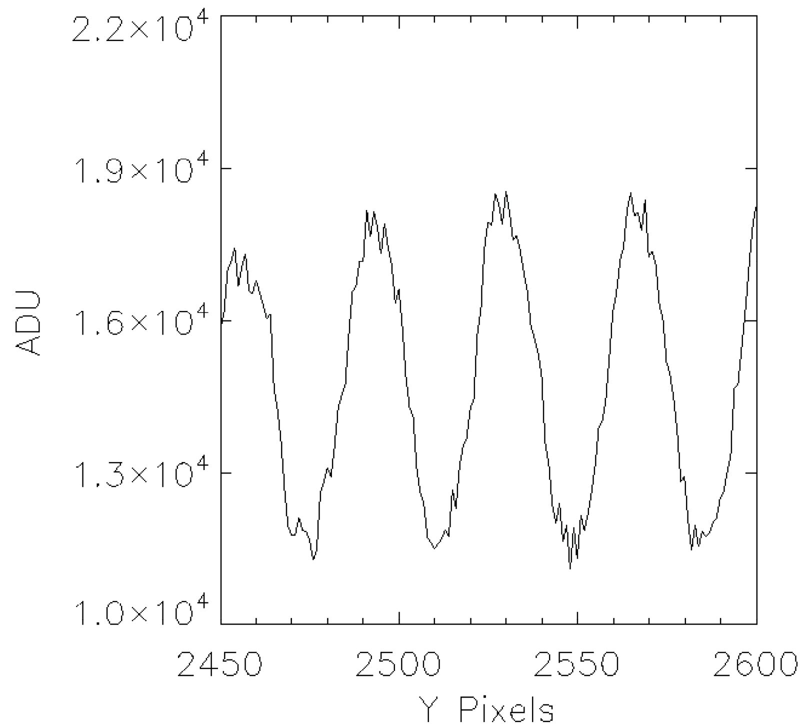


**Figure 5.** The intensity of meteor breaks along Y axis.

Starting a remote and automated camera network has many challenges. A single image from the LH11000 camera is 20 MB in size. This results in 400+ GB of raw data every night from a single camera. One of the big challenge is to develop a very fast and yet efficient and automated method to detect meteor. The false detections have to be limited, as the number of images that can be transferred are limited by low bandwidth internet. One of the most important factors in computing precise orbits of meteoroids is to estimate the meteor position in the image with less than 1 pixel uncertainty. Most of the software for processing meteor images were written for off-the-shelf cameras, and many modifications would have to be made so that the required accuracy can be achieved. Other challenges include developing a cooling system for the camera to reduce CCD noise while heating up the lens area to prevent condensation.

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