International Occultation Timing Association
European Section

A Fast Digital CCD Camera with Precise NTP Time Stamping (GPS) for the Linux Operation System

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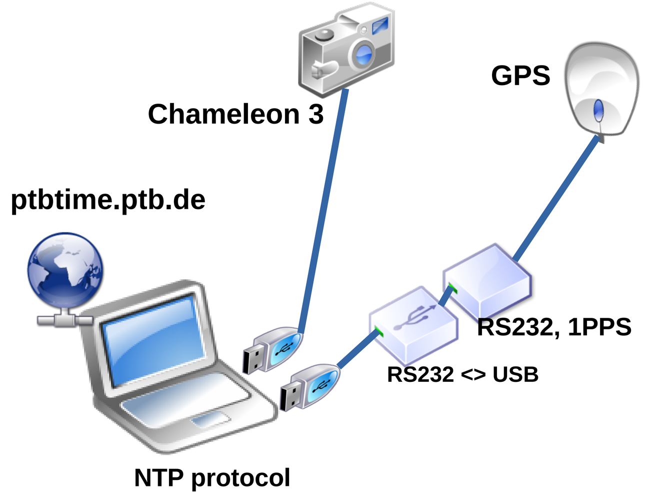
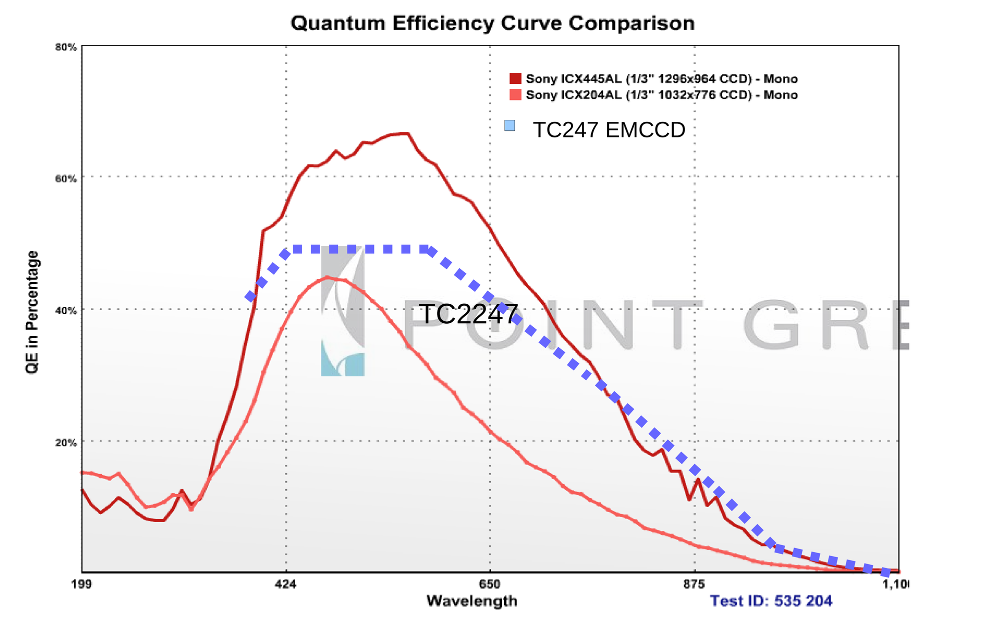
Abstract

Dedicated camera systems for use in occultation astronomy and/or photometry need a precise time-stamping facility. For both applications instruments with more than 8 bit intensity resolution are required. Only, if occultations by atmosphereless bodies are recorded, analogue recording can be the matter of choice. However, in may cases precise photometry of the signal is important. In this report the combination of an industrial camera with a special recording software for LINUX is described. A timing accuracy of +/- 6 msec using a GPS receiver with 1pps facility has been achieved. The camera system generates FITS images with the appropriate timestamp keywords.

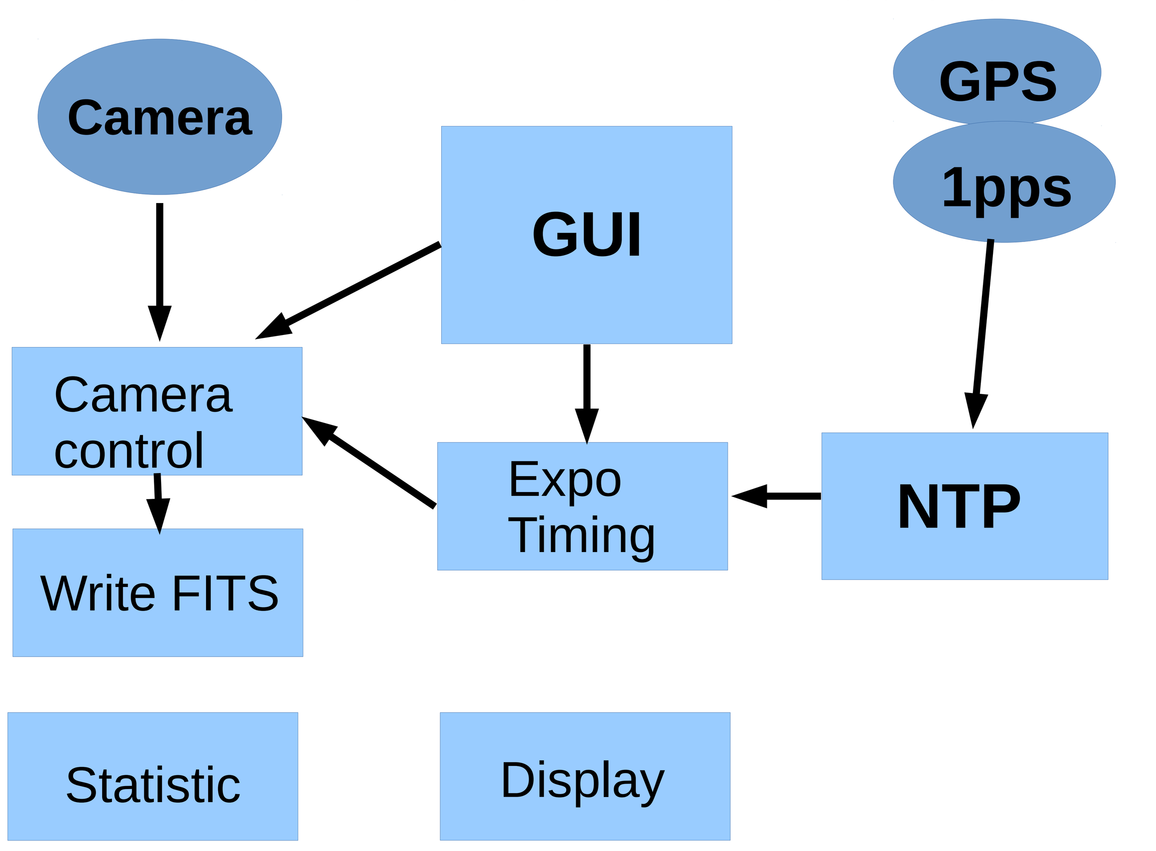
Principle Components



Comparison QE Standard CCD vs. EMCCD (TC247)



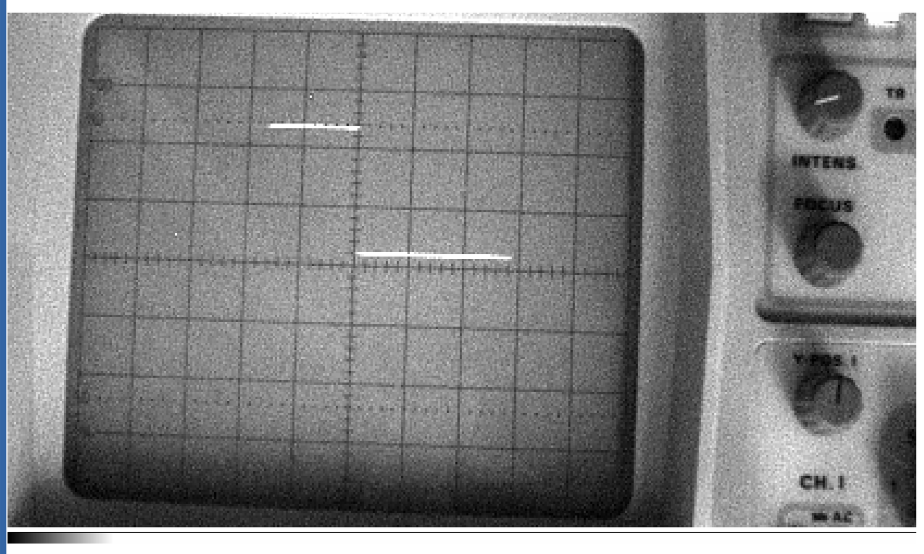
Overview of software structure



A graphical user interface with the DISLIN package of the Max Planck Institute for Solar System Research has been used for writing the GUI.

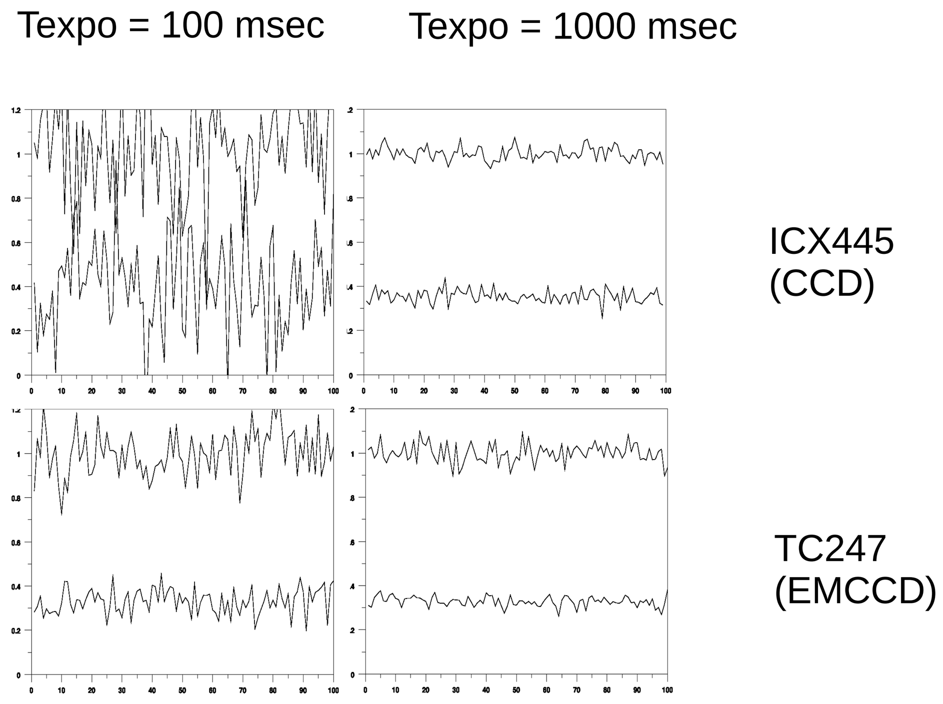
During extensive testing the average accuracy of the time stamp has been found to be better than ± 6 msec. Comparisons have been done successfully with an internet NTP time server, such as www.ptbtime1.de generated by the Physikalisch Technische Bundesanstalt Braunschweig as well as with an external GPS receiver using the 1PPS signal.The jitter has been found to result from the internal firmware of the camera itself.

Measuring the time precision by use of the 1PPS signal of GPS receiver



Recording of a 1pps signal pulse fed to an oszilloscope. The screen of the oszilloscope is imaged by the running camera. From the leading or trailing edge of the 1pps signal from a GPS receiver the deviation of the time stamp in the image can be determined. At an average the deviation could be determined to about **+/- 6 msec** as the most. This is by far precise enough for astronomical applications.
With an average relative velocity of 20 km/sec of the observer and the occulting object, the error in position has a maximum of about 120m.

Visualisation of recording using CCD and EMCCD camera sensor



In each graphic the upper track shows a 14m2 star, the lower a 15m4 star. Recorded with either 100msec or 1000msec exposure time of each image.
Data points of 100 images are shown for each track. Recorded with a 50cm ¼ Newtonian instrument from HAKOS, Namibia, IAS.
The advantage of a EMCCD sensor versus a standard CCD chip for short exposure times can clearly be seen. At 1000 msec exposure time, the advantage of EMCCD is rather small.

Summary

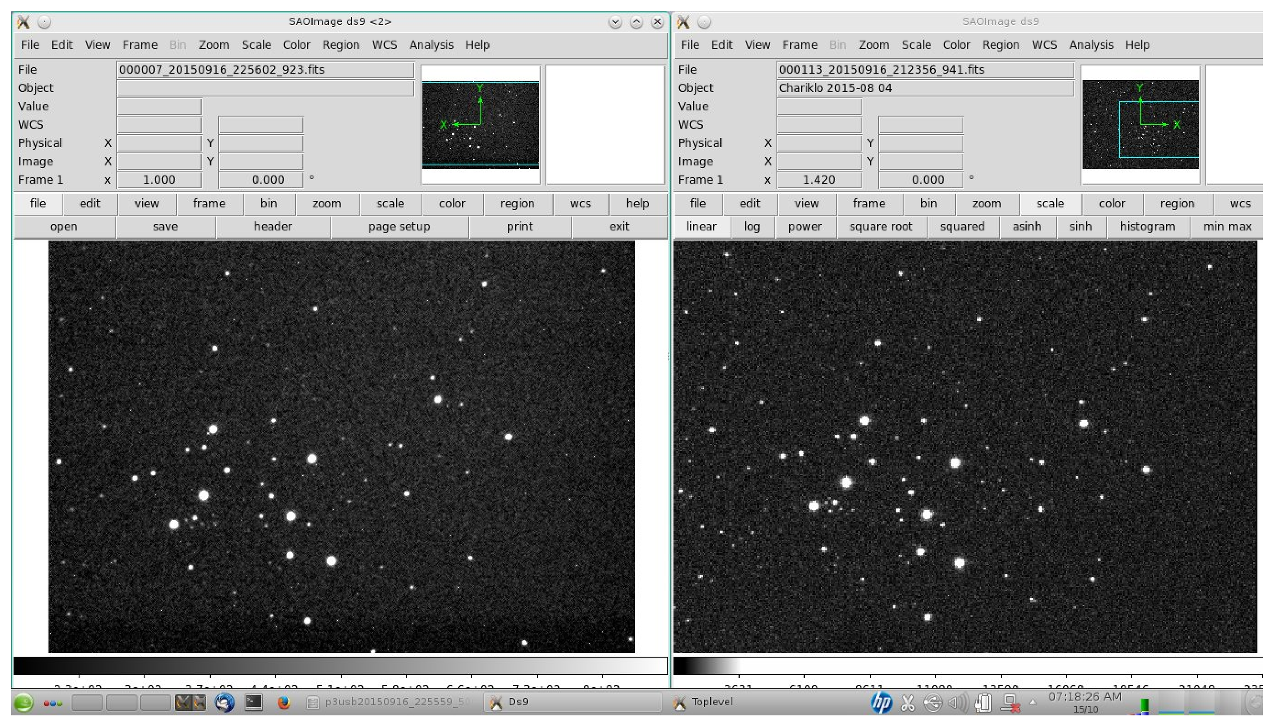
On the basis of an industrial CCD camera with 12 bit resolution, a system has been developed for occultation astronomy and photometry with generated time stamps with an accuracy of about 6msec. Maximum frame rate is 30 fps. It is well suited to be distributed in the PRO-AM community to replace analogue video recording systems still in use in many small observatories.

Properties of Camera (Chameleon 3, Point Grey)

- Low cost (single unit price of camera head around 300 €)
- Up to 30 full frames per second
- 7 electron readout noise
- Pixelsize 3.75 x 3.75 µm
- 73% peak quantum efficiency
- 1/3 inch size, ICX445 (Sony)
- 1.3 Mpixel reduced to 640x480 by 2x2 bininng (7.5x7.5µm)
- Resolution 12 Bit
- No Gap between consecutive images
- Family of cameras with different sizes and price tags
- LINUX software development kit available
- USB3, USB2 connectivity
- Forced ventilation, keep temperature down to ambient + 8°C
- Weight 100g

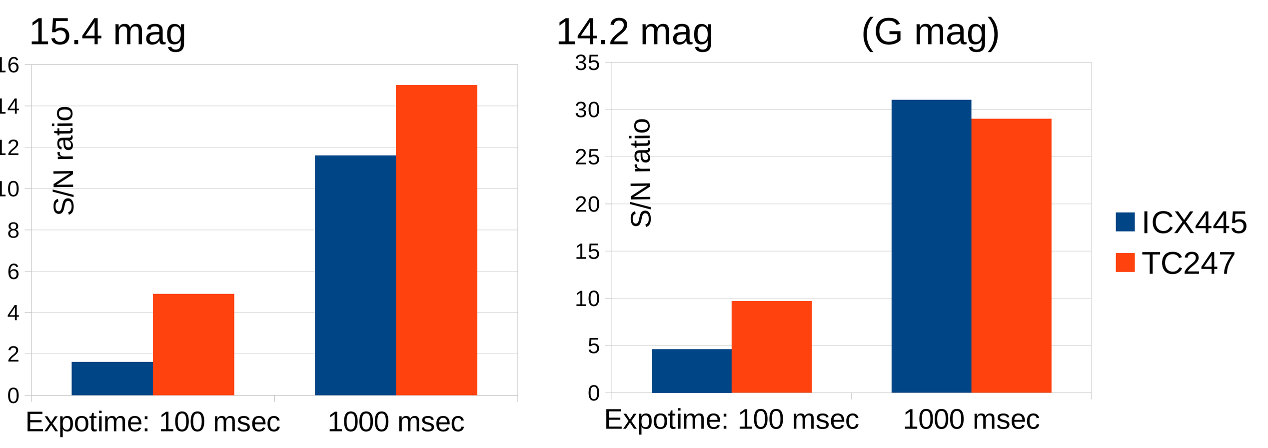
Performance check of the camera system

Comparison CCD vs. EMCCD for M29 (0.27m SCT, 1/3.5 (f=1000mm), no filter



ICX 445 (PTGrey, Chameleon 3) TC247 (Raptor)
Texpo = 500 msec

Comparison of S/N ratio for 2 stars with EMCCD TC247 and ICX445. Telescope: 500mm 1/4



The S/N ratio of a EMCCD is for short exposures (100msec) reasonable lower as for a CCD. At longer exposure times (1000 msec) both S/N ratios starts to equilibrate.

Example in occultation astronomy, Occultation by Triton, 2017, Telescope 270mm 1/7