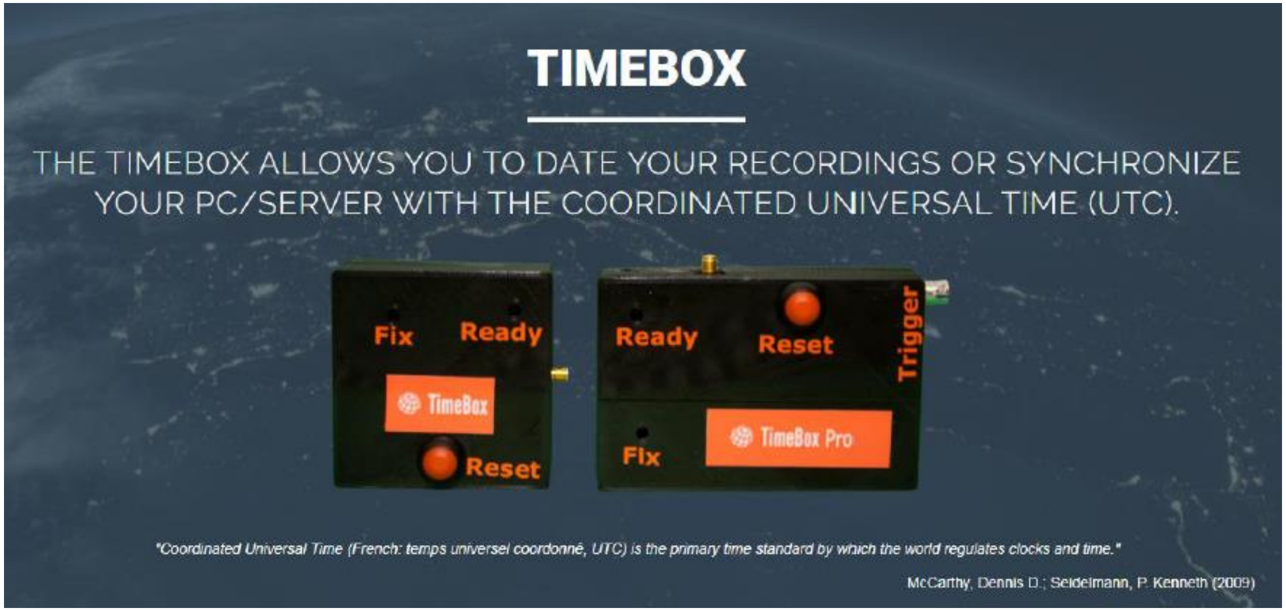
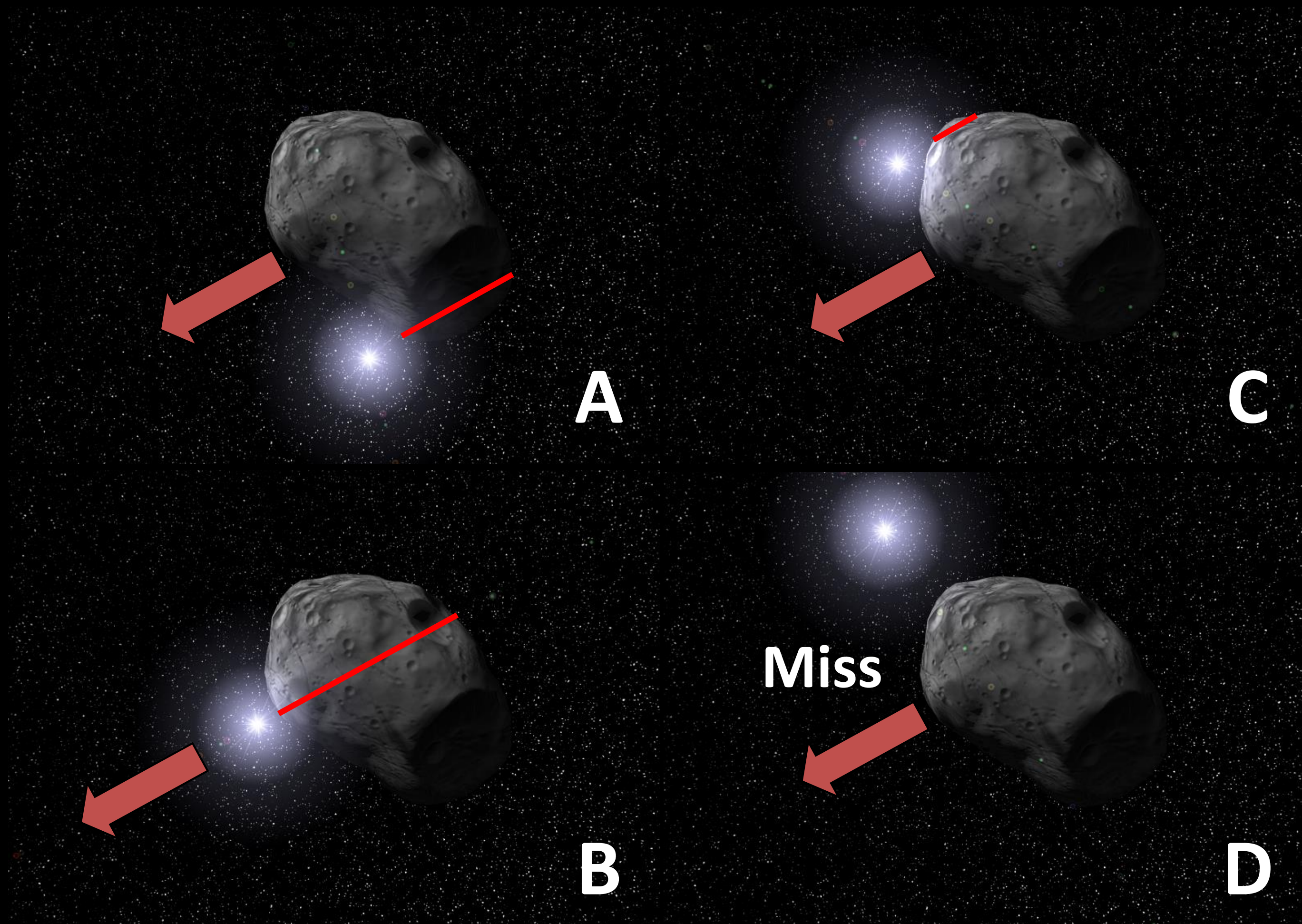
TimeBox

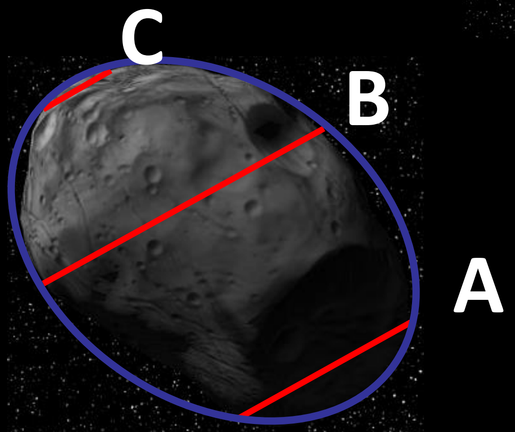


Timing Issues in occultations using a PC

Cesar VALENCIA GALLARDO, Ph.D.
TimeBox CEO and Founder

IOTA-ES, 38th European Symposium on Occultation Projects (ESOP 2019).
30th August-1st September 2019. Observatoire de Paris. Paris, FRANCE





Asteroid Occultation

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Asteroid occultations present great qualities:

- Direct measure.
- Precise angular resolution.
- Available for Amateurs (Moderate cost and Freeware for predictions and analysis).

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To correctly perform an asteroid occultations you need:

- Prediction (Occult, OccultWatcher, Steve Peston website, Euraster, etc.)

- Telescope.

- Camera (analogic/digital) → Produce linear photometry (Raw/untreated images).

- **Method to correctly date your recording with a standard time base → UTC = Universal Time.**

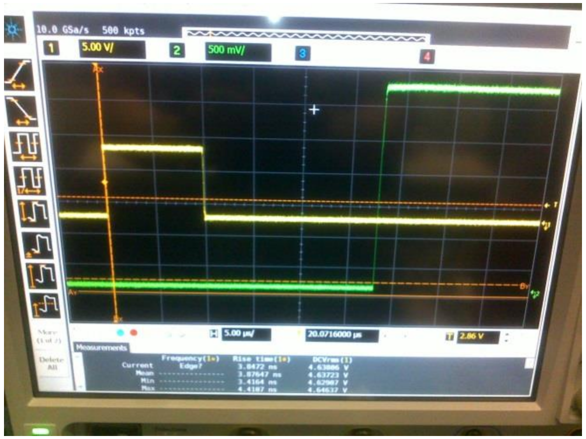
UTC time in astronomy

Get the UTC (Coordinated Universal Time) from GPS satellites with great precision (±1000-200nSec UTC, 1PPS).

Astronomy

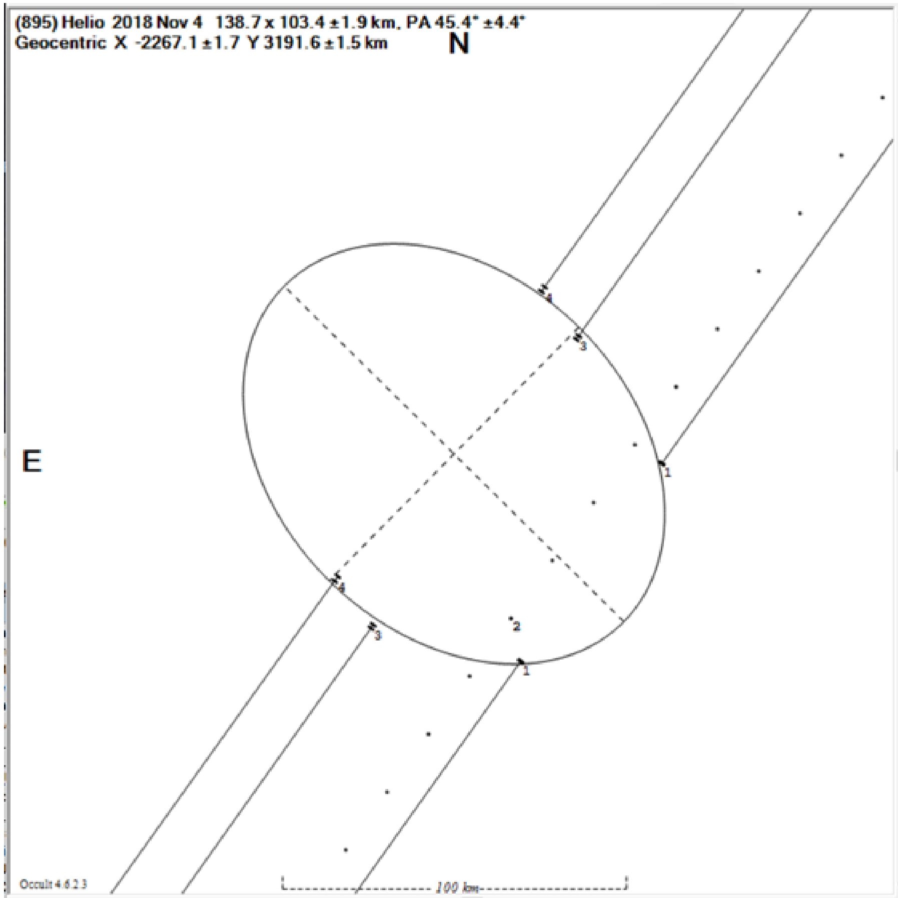
- Astrometry.
- PHEMU's.
- Occultations (Asteroid, TNO, Planets and Moon)
- Pulsar timing.

PC time synchronization.



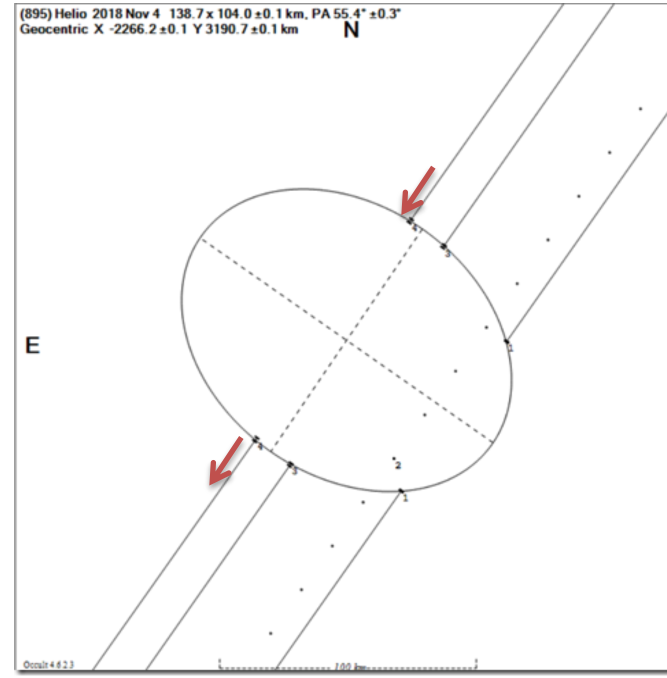
SYRTE (CNRS, Observatoire de Paris) Atomic Clock tests.

TimeBox

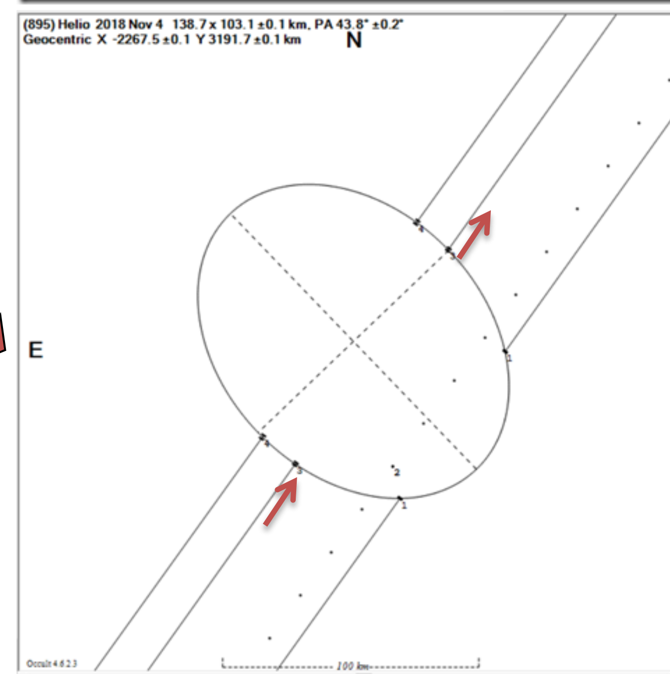


(895) Helio 2018 Nov 4 138.7 x 103.4 ±1.9 km, PA 45.4° ±4.4°
Geocentric X -2267.1 ±1.7 Y 3191.6 ±1.5 km
N
E
Occult 4.6.2.3
100 km

?

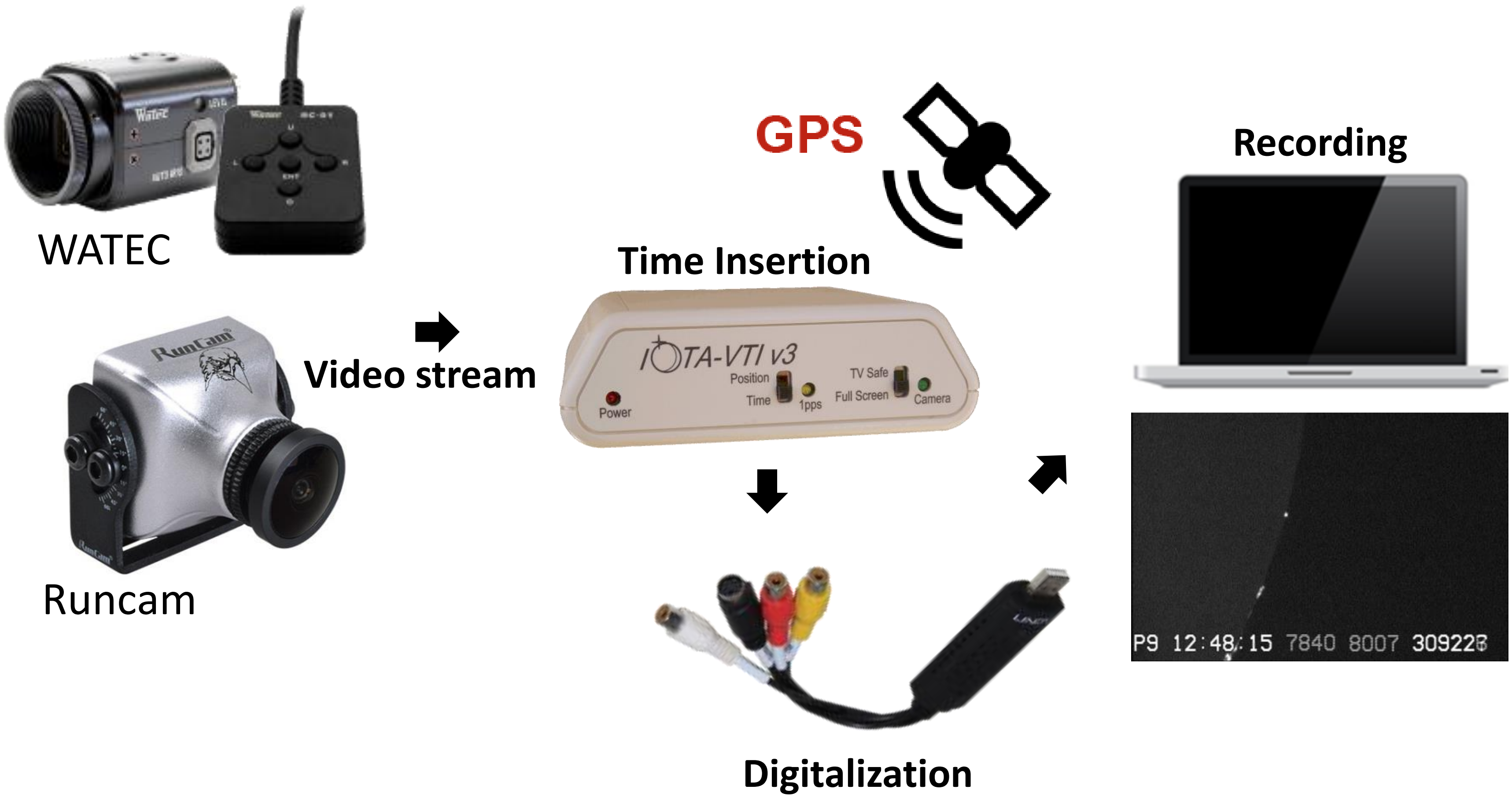


(895) Helio 2018 Nov 4 138.7 x 104.0 ±0.1 km, PA 55.4° ±0.3°
Geocentric X -2266.2 ±0.1 Y 3190.7 ±0.1 km
N
E
100 km



(895) Helio 2018 Nov 4 138.7 x 103.1 ±0.1 km, PA 43.8° ±0.2°
Geocentric X -2267.5 ±0.1 Y 3191.7 ±0.1 km
N
E
100 km

Analogic recording with Time Inserter



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Issues with the Analogic recording:

- **Availability** of latest sensitive and low noise image sensors (Sony STARVIS, sCMOS, EMCCD, etc.) → Lower image quality and higher noise.

- Lower Frame rates selection and **recording parameters** → Binning, Gain/EM Gain, ROI, etc.

- Possible image quality **degradation** before digitalization (cabling).

UTC precision timing using Digital video devices

Most amateur CCD and CMOS Cameras are digital → Planetary imaging, Autoguiding, etc…

Basler

TIS (DMK)

IDS

ZWO

New CMOS image sensors and Cameras arriving in the market! → **Digital**

Raptor Kite EMCCD

Andor Neo 5.5 sCMOS

AiryLab

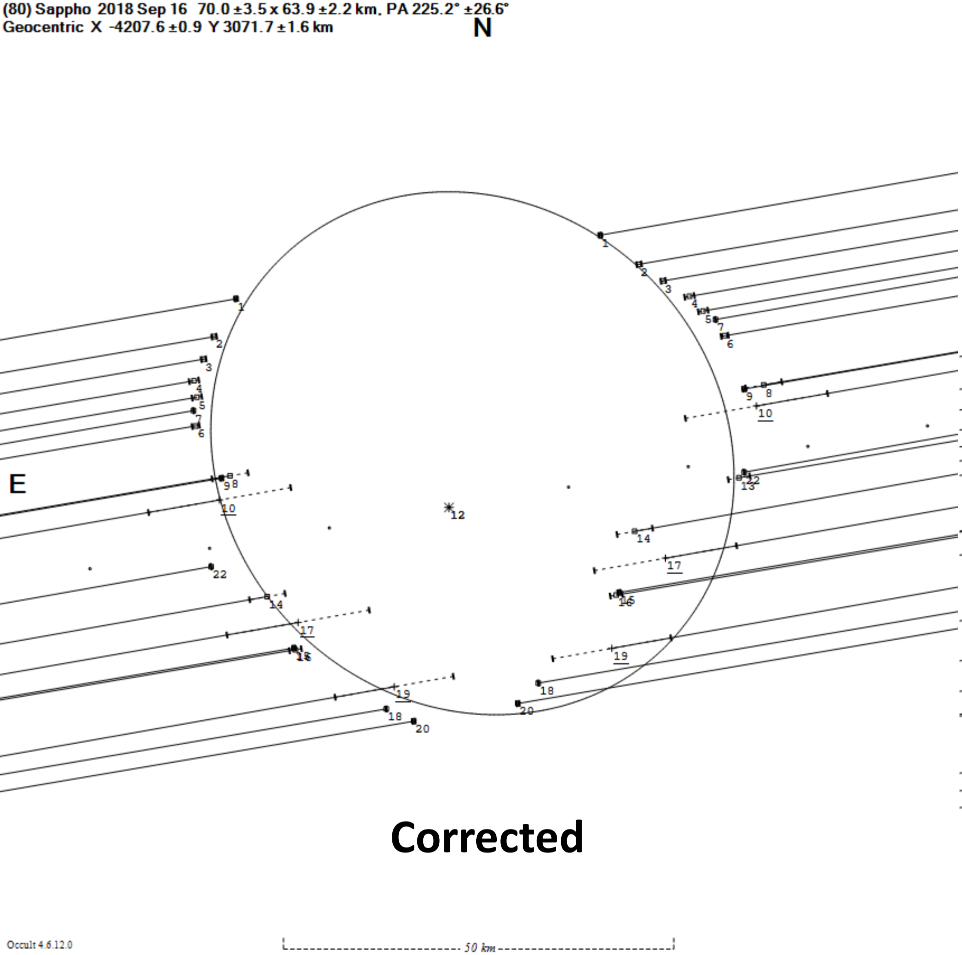
Genika (Windows)

~90.5% Windows
~7.72% Mac OS X
~1.74% Linux
~1.37% Others

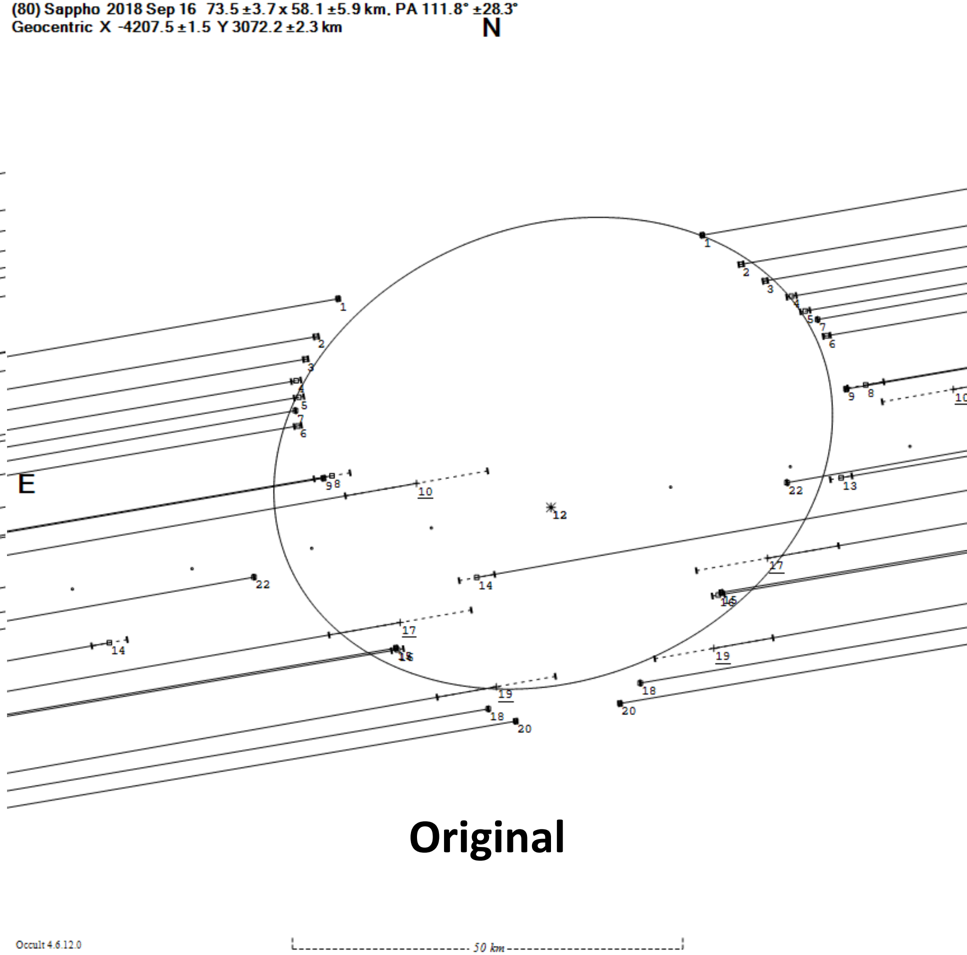
Professional CCD, EMCCD and sCMOS digital

Photonics Evolve EMCCD

Bad recording can be catastrophic!



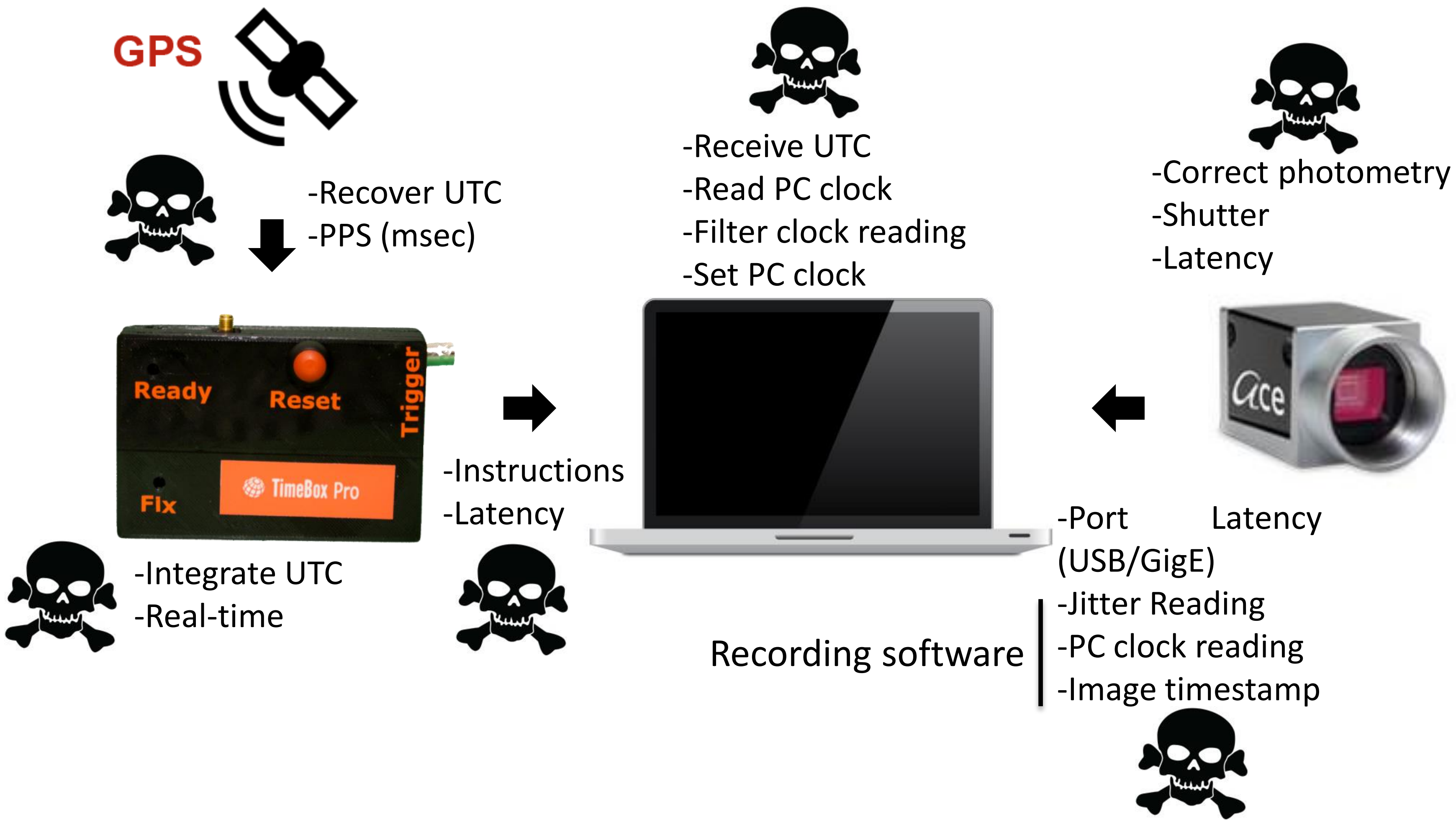
Corrected



Original

TimeBox

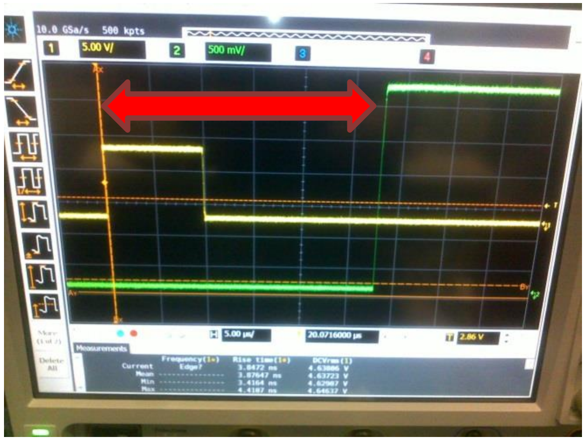
Occultations with using PC/digital camera



UTC acquisition and timeline

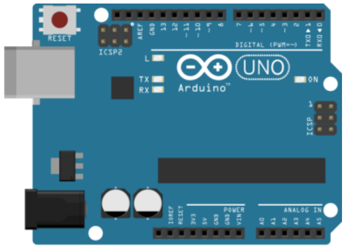
-Recover UTC
-PPS (msec)

-Integrate UTC
-Real-time



Measure difference SYRTE UTC vs. Device GPS PPS

Results delay of 200 nsec



Arduino integration:

Real Time system
-ATmega328P

~~Rasberry Pi~~
~~Intel Galileo~~ → OS

TimeBox

Occultations using PC/digital cameras

Basler

TIS (DMK)

IDS

ZWO

-Correct photometry
-Shutter
-Latency

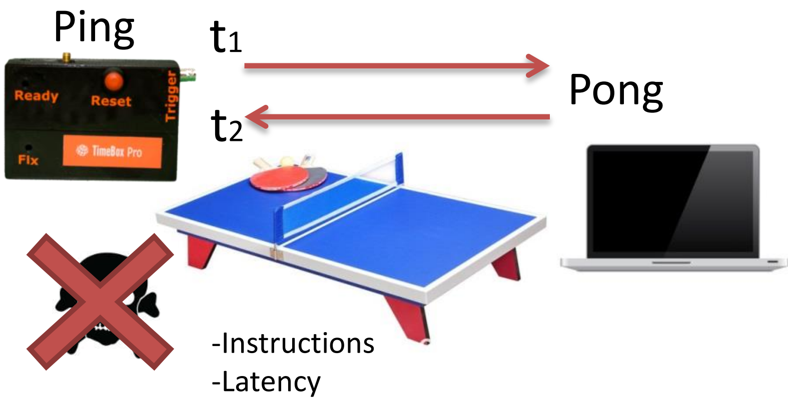
Raptor Kite
EMCCD

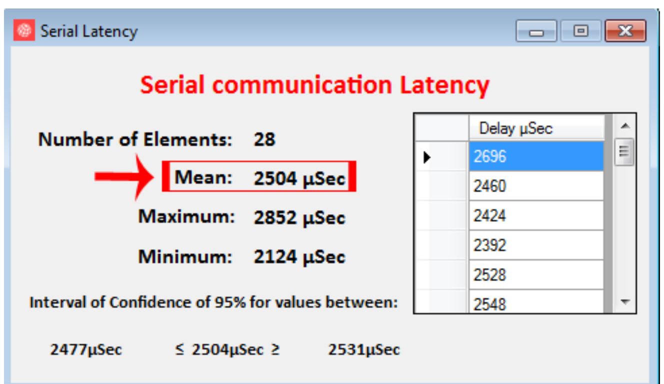
Andor Neo
5.5 sCMOS

Photonics
Evolve
EMCCD

TimeBox

Dealing with USB serial latency

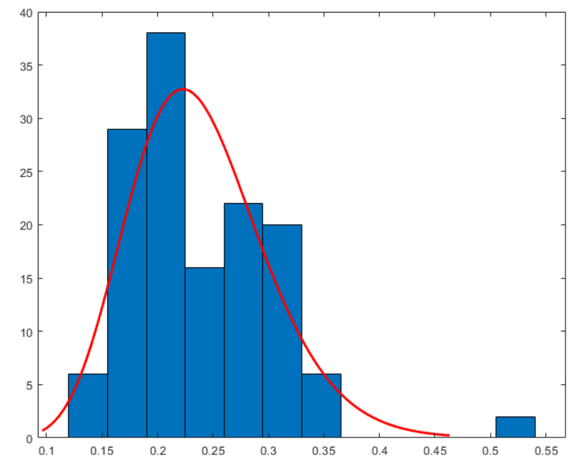




$$\text{Serial delay} = \frac{t2 - t1}{2}$$

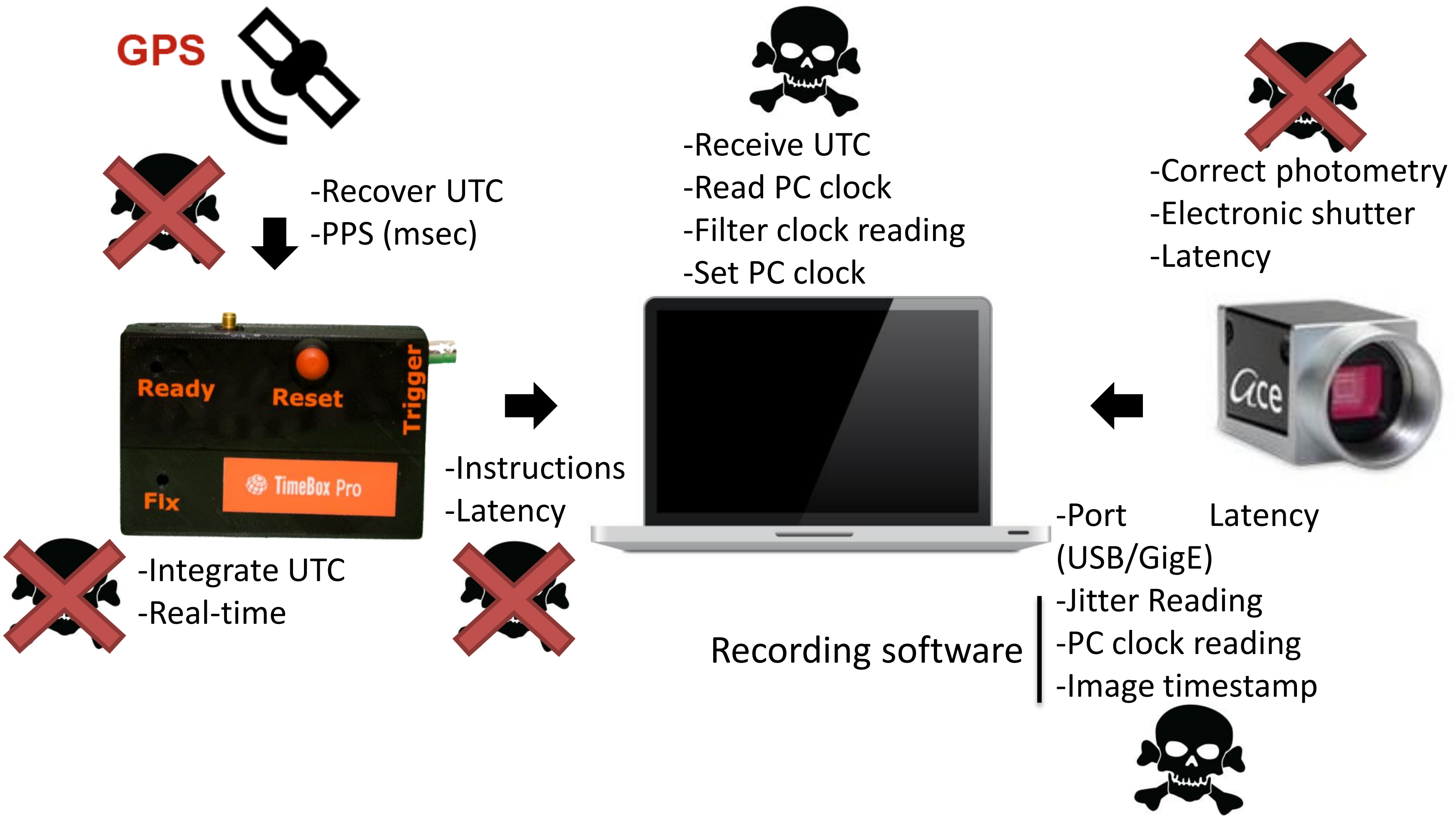
Ping: TimeBox

Pong: AMD FX-8350 4 GHz, USB2 Serial comm.



Median = 2144 µsec ± 528 µsec

Mean = 2383 µsec ± 651 µsec


GPS
-Recover UTC
-PPS (msec)
-Receive UTC
-Read PC clock
-Filter clock reading
-Set PC clock
-Correct photometry
-Electronic shutter
-Latency
Ready
Reset
Trigger
Fix
TimeBox Pro
-Instructions
-Latency
ace
-Port (USB/GigE)
Latency
-Jitter Reading
-PC clock reading
-Image timestamp
-Integrate UTC
-Real-time
Recording software

Acquiring UTC time in Windows

- **GetSystemTime()** Minimum: Windows 2000
  Retrieves the current system date and time. The system time is expressed in Coordinated Universal Time (UTC). Resolution 1-2 msec, vary from different systems.

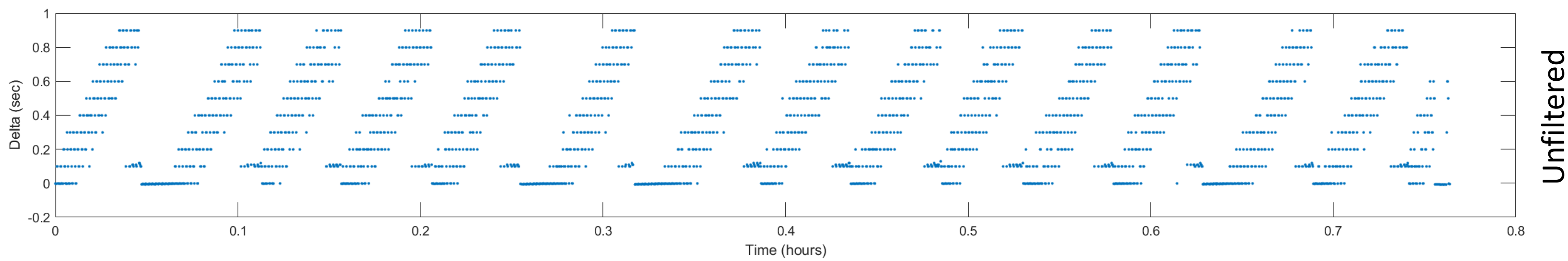
- **GetSystemTimePreciseAsFileTime()** **Minimum: Windows 8**
  Retrieves the current system date and time with the highest possible level of precision (<1us). The retrieved information is in Coordinated Universal Time (UTC) format.

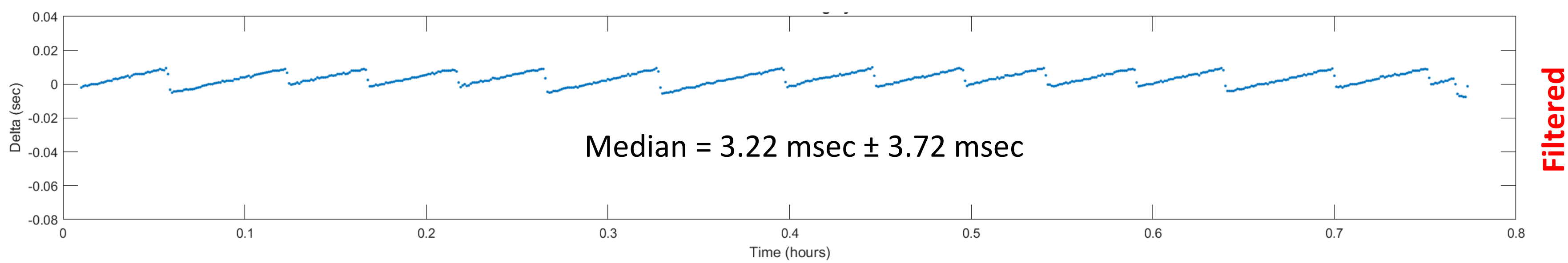
TimeBox

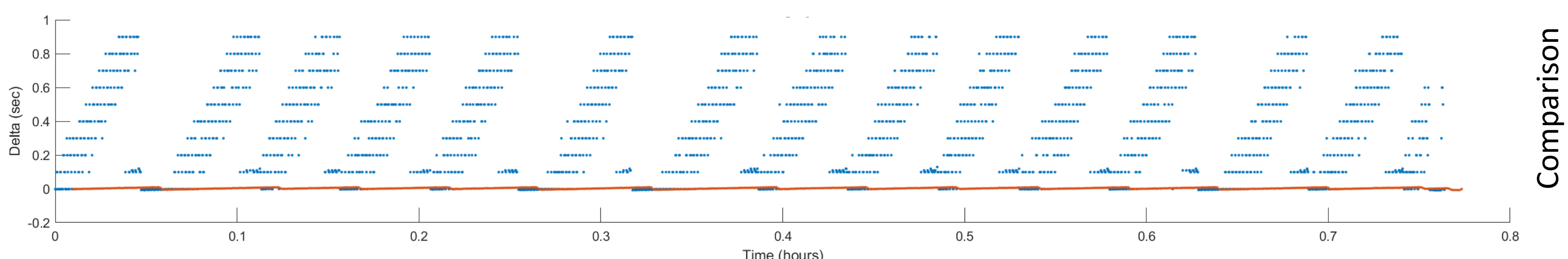
Acquiring and filtering UTC timestamps

Log file contents:

- ✓ RAW timestamp of the PC vs TimeBox
- ✓ Mathematical **filter** of the timestamps → Stable timebase

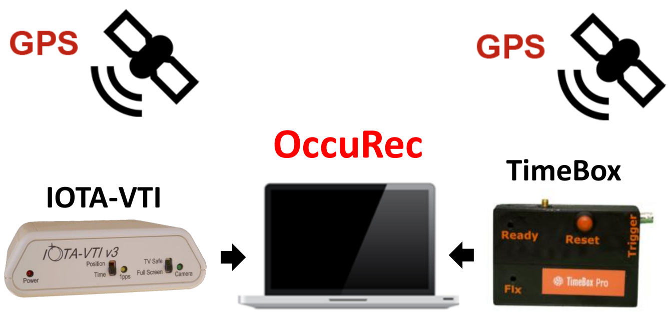






Tests made by Lionel ROUSSELOT

PC time-base for long periods of time

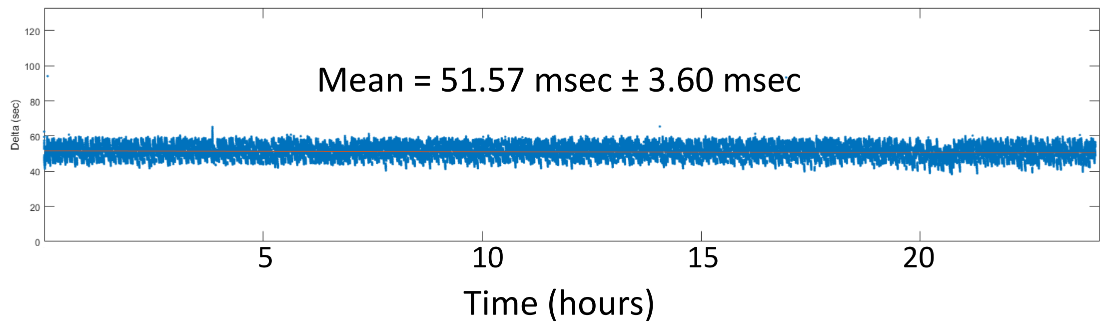


2 million timestamps (25 fps x 24 hours)

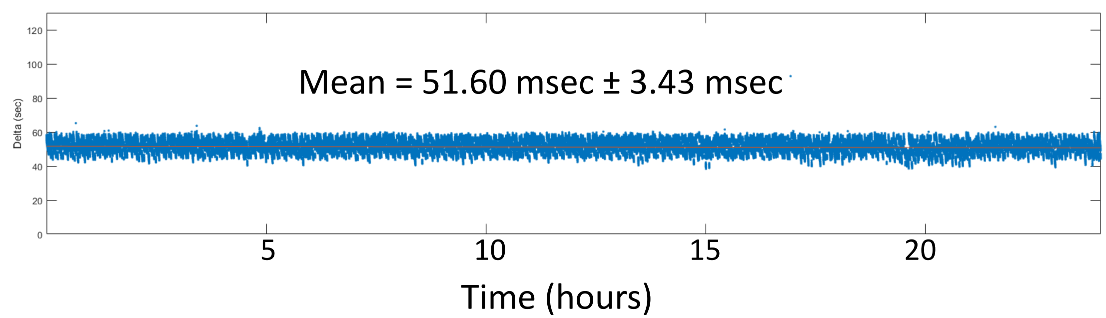
Compare the timestamp of the IOTA-VTI frames header vs. the PC clock synchronized with the TimeBox.

- ✓ Constant delay from the Frame grabber
- ✓ Stable timeline for extended periods

DAY 1



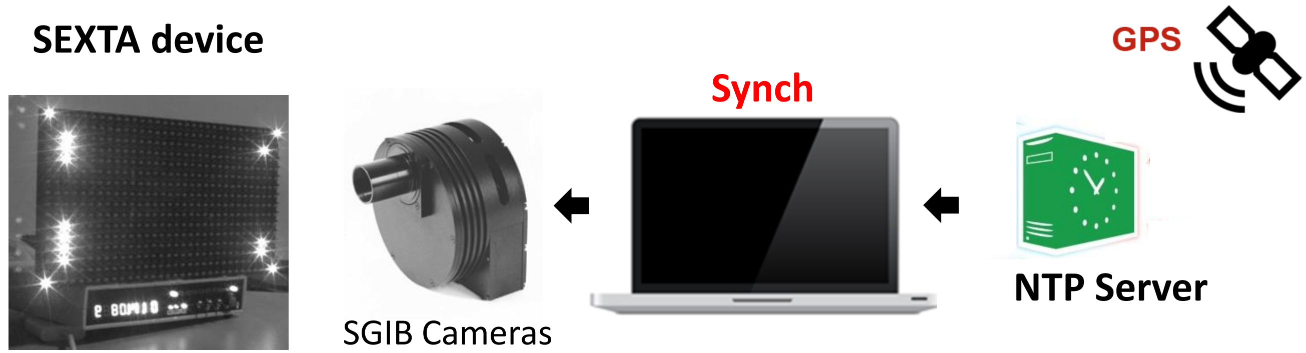
DAY 2



Tests made by Hristo PAVLOV and Dave GAULT

TimeBox

Not all recording software are adequate



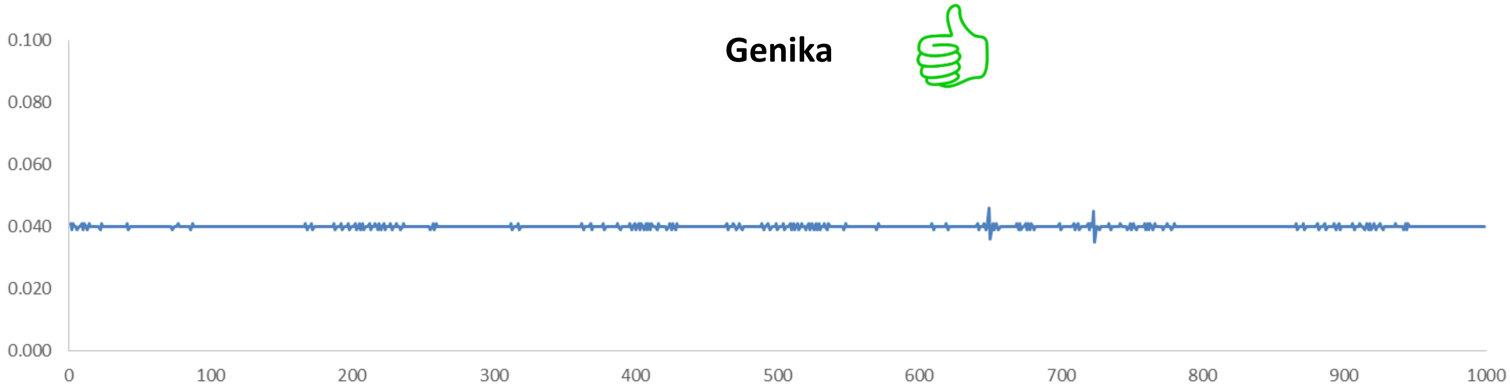
- **SBIG CCDOPS**
  CCDops timestamp resolved to the second.
  Average Offset +115 msec with a jitter of -32 to +408 msec
- **SBIG CCDSOFT**
  CCDSoft timestamp resolved to the millisecond.
  Average Offset +79 msec with a jitter of ±17 msec.
- **MAXIM DL**
  MaximDL timestamp resolved to the centisecond.
  Average Offset +802 msec with a jitter of ±20 msec.

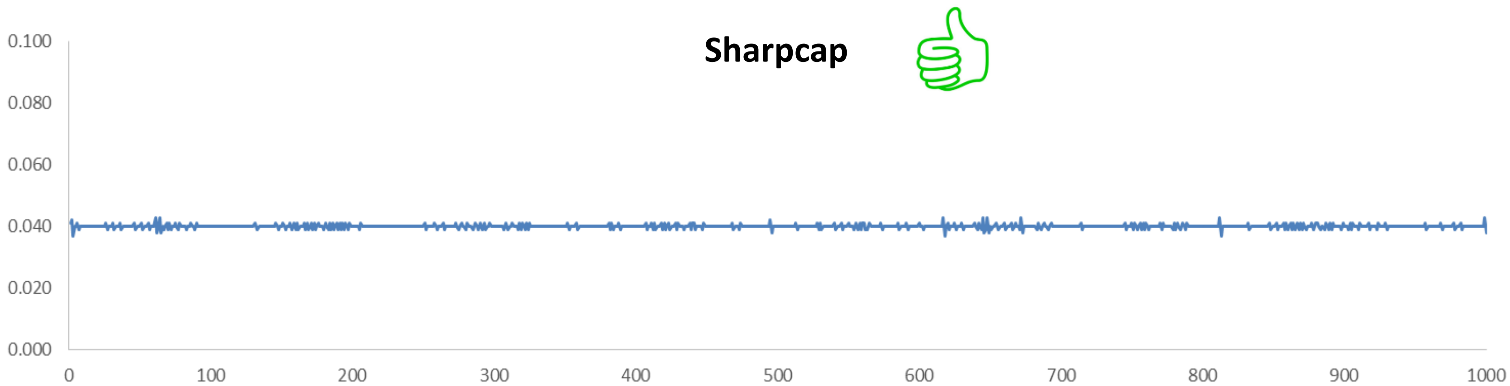
Tests by
Tony Barry, Dave Gault *et al.*

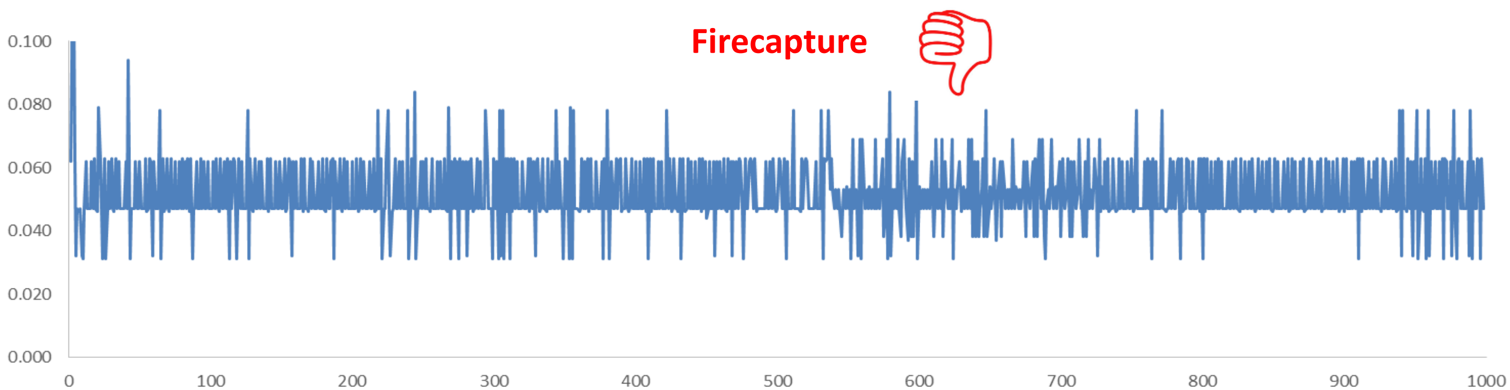
Tony Barry, **Dave Gault**, Greg Bolt, Alistair McEwan, Miroslav D. Filipovic and Graeme L. White. Verifying timestamps of occultation observation systems (2018). Publications of the Astronomical Society of Australia (PASA) Astronomical Society of Australia 2018. doi: 10.1017/pas.2018.xxx.

TimeBox

Acquisition software is vital for precision







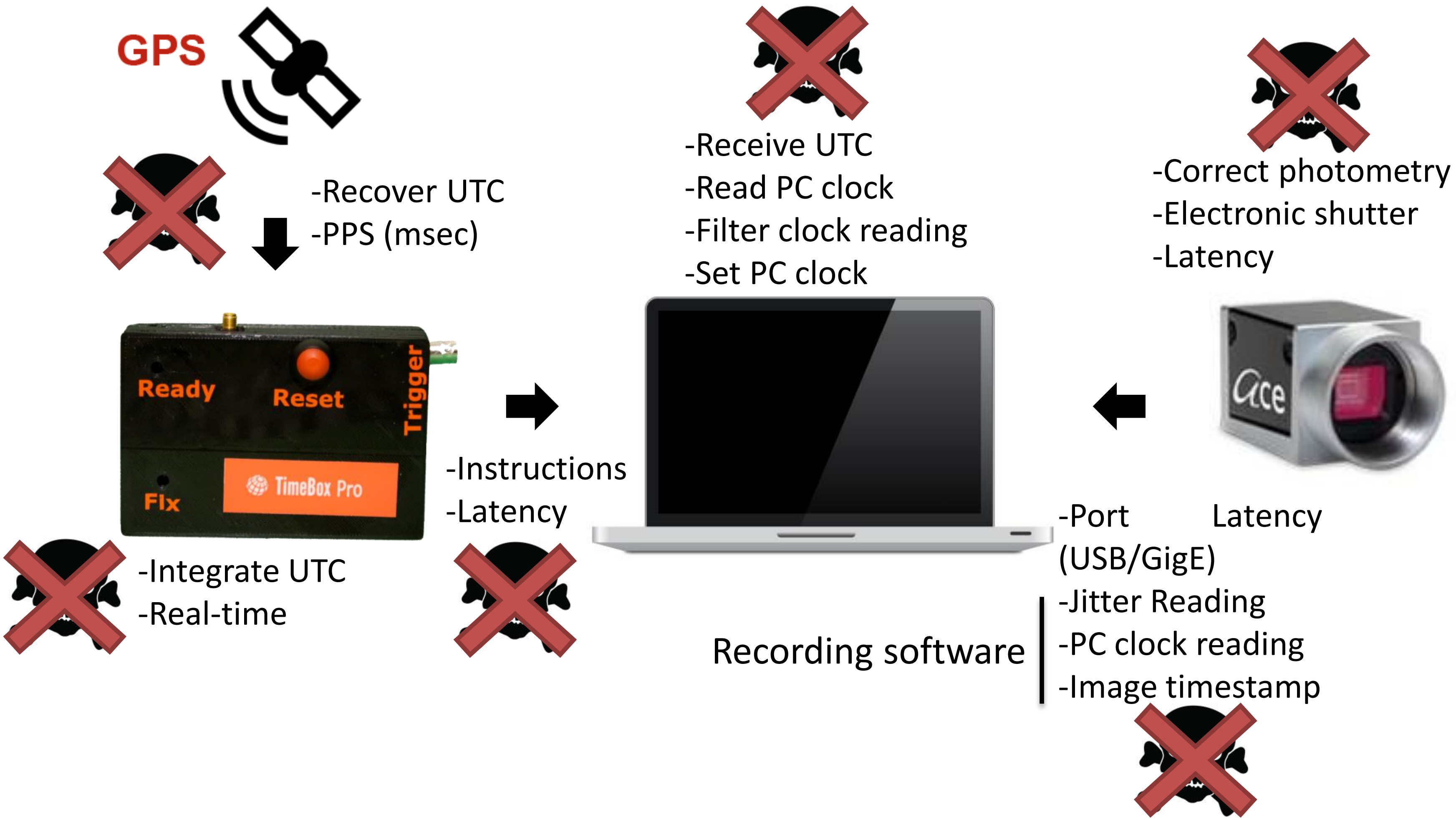
Conditions:

- 1000 images
- Extraction timestamp
- Time between two images

Regularity?

Camera: ZWO 1600
Exposure: 40 msec
No binning
ROI: 1320*1320

Tests made by Lionel ROUSSELOT


GPS
-Recover UTC
-PPS (msec)
Ready
Reset
Trigger
Fix
TimeBox Pro
-Integrate UTC
-Real-time
-Instructions
-Latency
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-Filter clock reading
-Set PC clock
-Correct photometry
-Electronic shutter
-Latency
ace
-Port (USB/GigE) Latency
-Jitter Reading
-PC clock reading
-Image timestamp
Recording software

Does this work???

IOTA tests with SEXTA device by Dave GAULT and Hristo PAVLOV

TimeBox

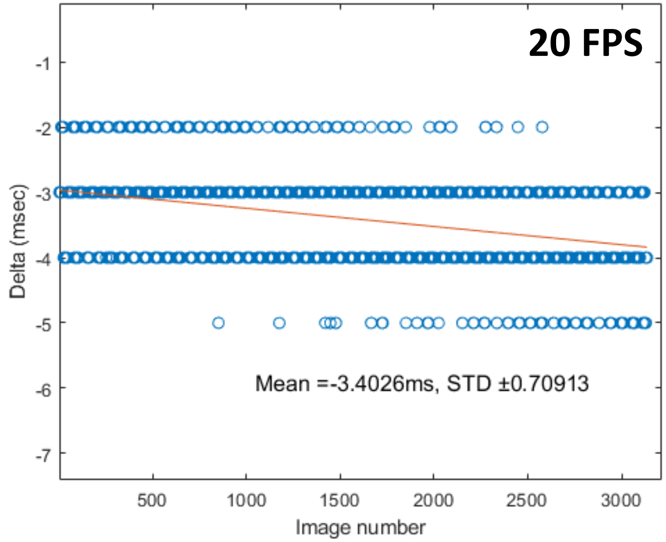
TimeBox vs SEXTA Computer mode

SEXTA device

Basler 640-100Gm

Synch
Genika

TimeBox



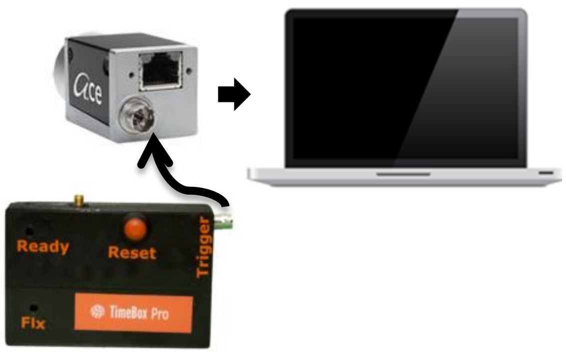
Exp. time (msec)	FPS	Delay (msec)
14	71	4.65
20	50	3.4
20	50	0.89
40	25	5.58
40	25	1.64
80	13	0.25
100	10	1.74
160	6	3.94
200	5	5.32
320	3	3.83
	Mean	3.12
	STD	1.88

Tests made Dave GAULT

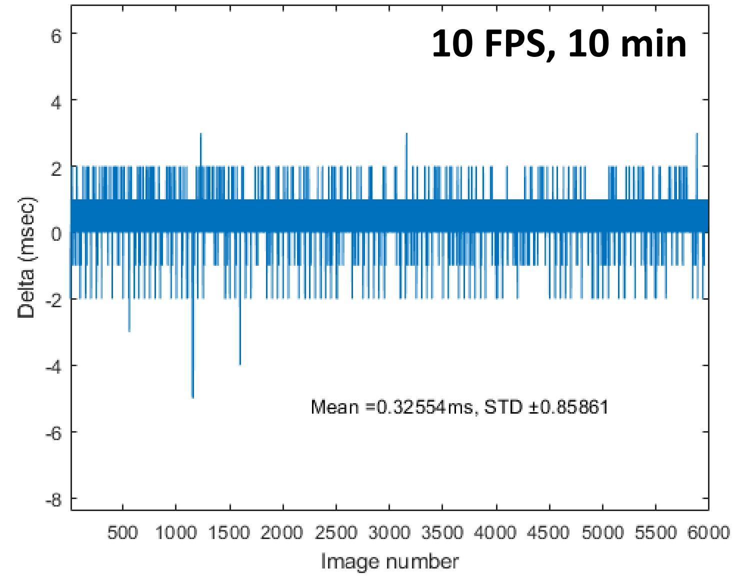
TimeBox vs SEXTA Trigger mode

SEXTA device

Trigger Genika



TimeBox

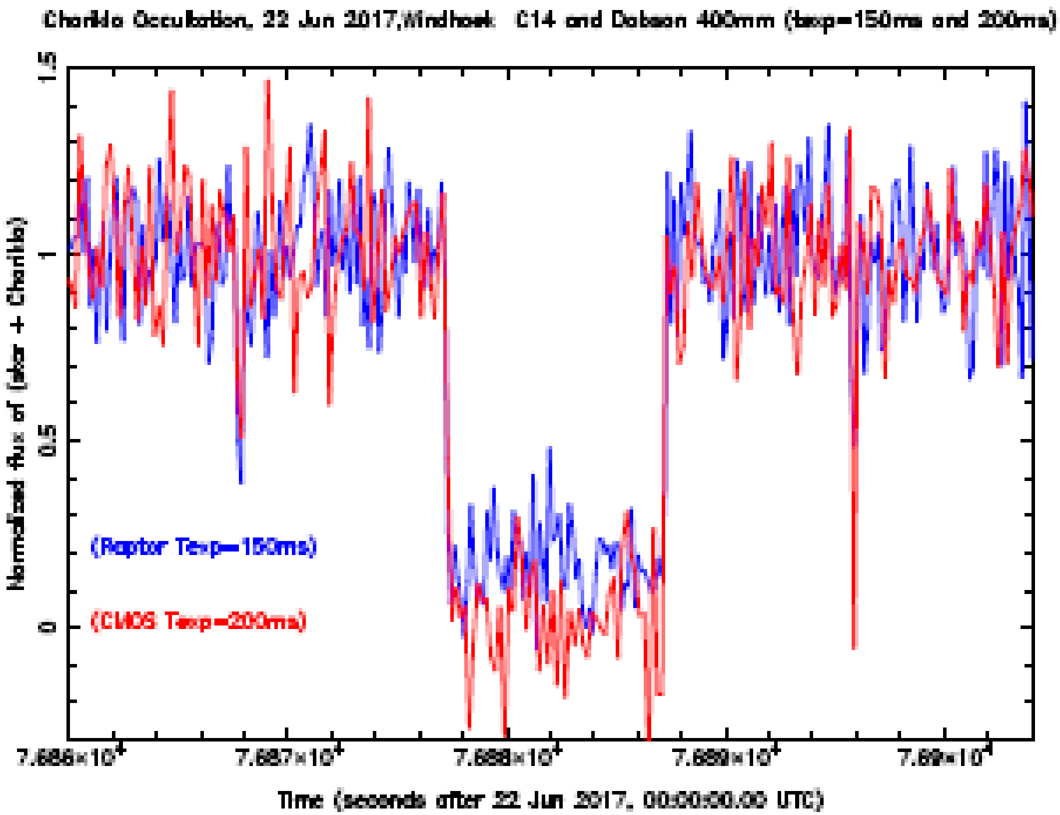


Short Tests (< 20 sec)		
FPS	**Delay (msec)**	**STD (msec)**
8	0.53	0.74
10	0.03	0.82
15	0.04	0.73
20	0.18	0.98
24	0.38	0.94
	Mean	0.23
	STD	0.11
Long Test (10 min)		
10	0.32	0.85

Tests made Dave GAULT

On the Sky occultations

Pr. Bruno SICARDY group, Chariklo 2018



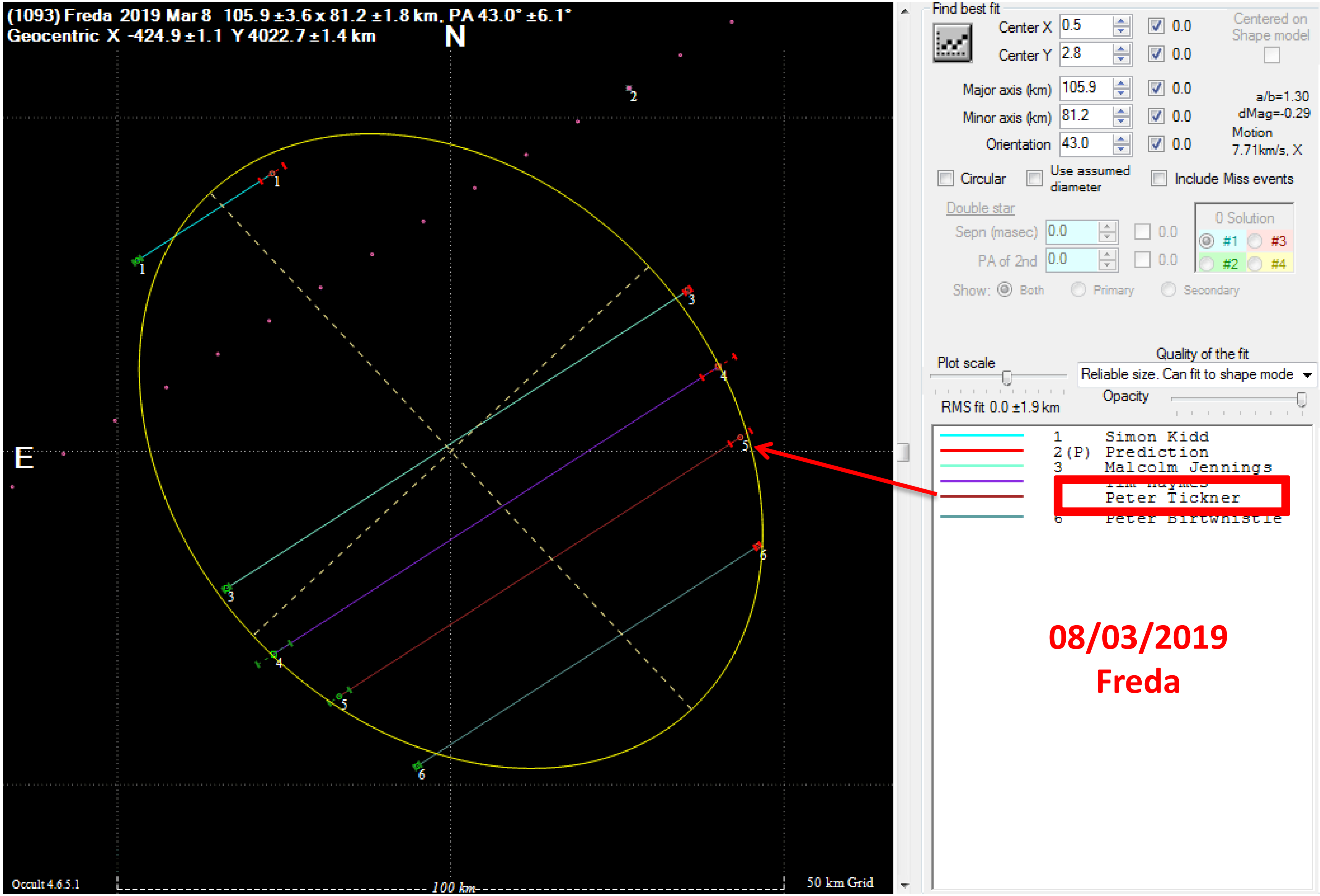
"Figure 3.5: Chariklo light curves observed during 2017. Note the abrupt drops of stellar flux in the case of an airless body like Chariklo. Left: Chariklo occultation light curves observed simultaneously on 2017 June 22 at Windhoek, Namibia. The blue and red light curves correspond to the Raptor Merlin and ZWO Cmos, respectively. It shows the consistency between the absolute time recording systems, down to the 0.1 second level..."

Meza *et al.* 2018

Erick Meza (2018). Observations d'occultations stellaires, applications à l'étude de la structure et l'évolution de l'atmosphère de Pluton. Doctoral dissertation, Université Pierre et Marie Curie - Paris VI, France.

TimeBox

Peter TICKNER, Freda 2019

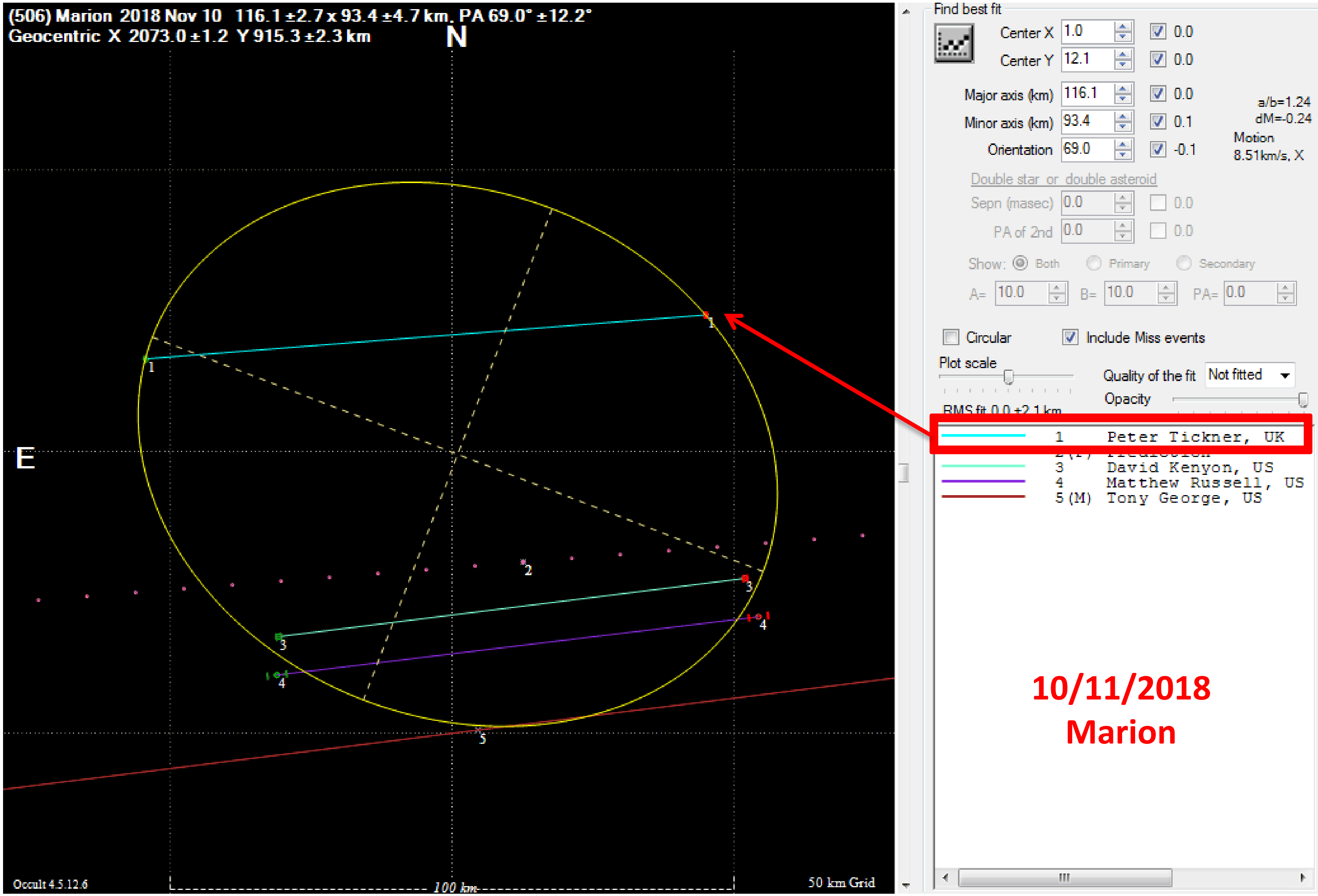


08/03/2019

Freda

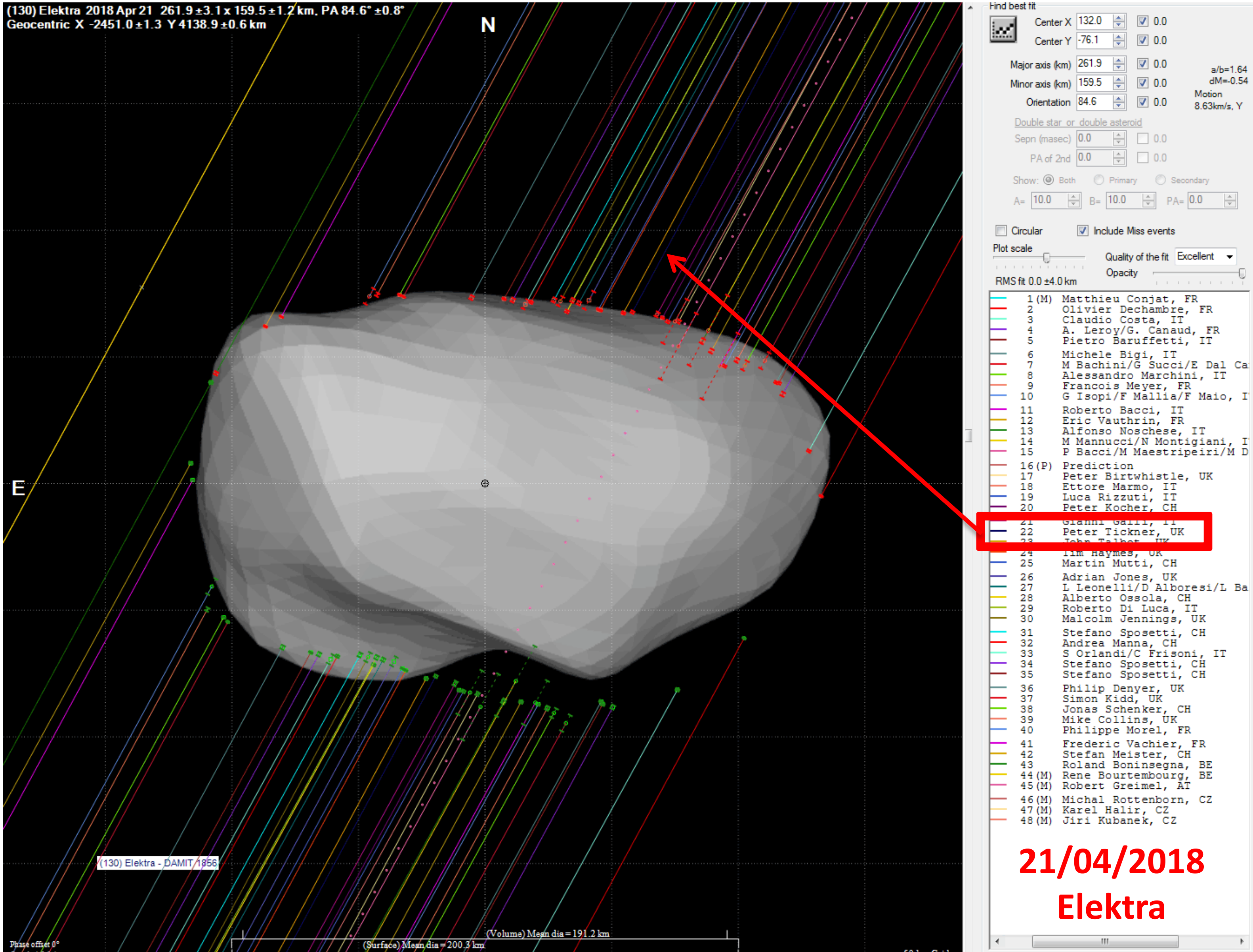
TimeBox

Peter TICKNER, Marion 2018



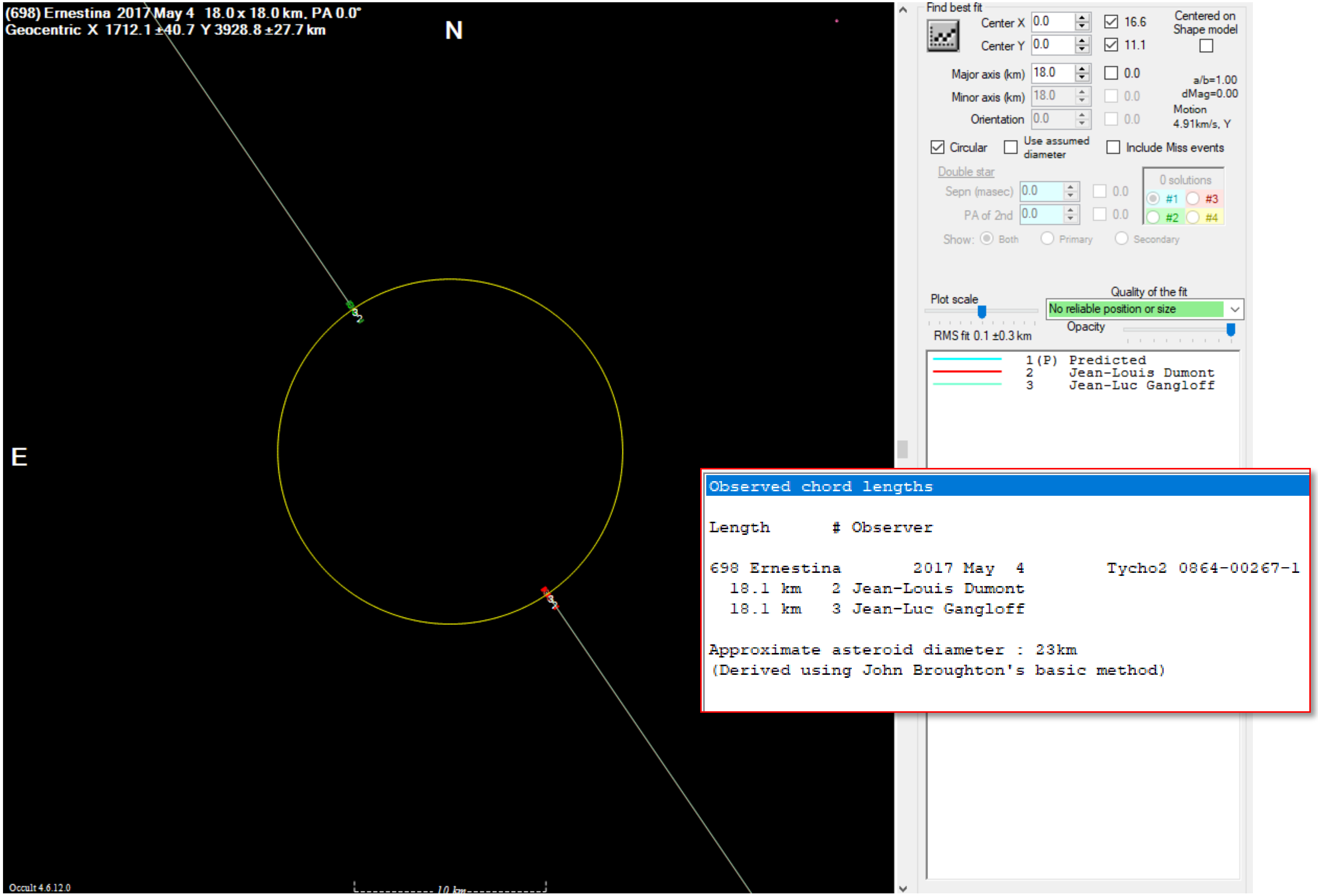
TimeBox

Peter TICKNER, Elektra 2018



TimeBox

Jean-Louis DUMONT, Ernestina 2017



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Conclusion: Possible using a PC for occultations

- ✓ Reliable GPS component with precise PPS.
- ✓ Real-time Stratum 1 device to acquire UTC.
- ✓ Calculate Serial latency.
- ✓ Recent CMOS/CCD camera in GigE/USB.
- ✓ Use new Windows PC clock reading method: GetSystemTimePreciseAsFileTime().
- ✓ Mathematical filtering of PC clock.
- ✓ Reliable video recording software.

Thanks for your attention

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sales@timeBOXutc.com