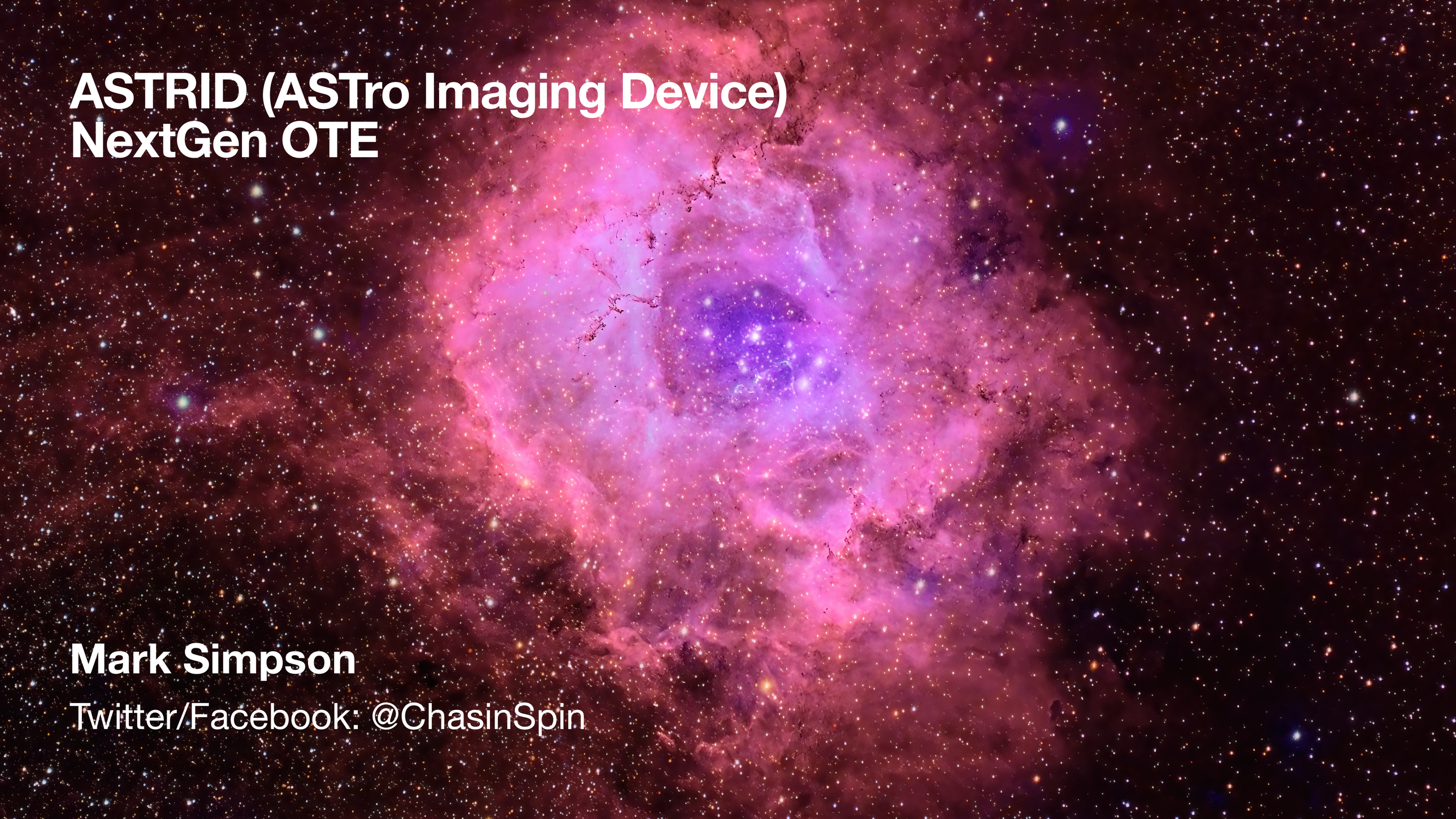
ASTRID (ASTro Imaging Device)
NextGen OTE



Mark Simpson

Twitter/Facebook: @ChasinSpin

An occultation beginner story…

- 19th Feb 2023 - 17km diameter/path asteroid(785) 1991 PK8 occults 40 Leonis for 1.5s
- No Camera
- Zero experience
- Find equipment (none ideal)
- Figure out the method
- Best practice older analog camera with GPS timestamp

Learnt…

- Scientists need this data
- Amateurs are a resource
- Very rare events
- One shot deals

Deployment…

- 4 Calgary RASC members
- 1 iPhone + screen timestamps
- 1 iPhone + Arduino GPS Flasher
- 1 QHY GPS Cam
- 1 ZWO Planetary Cam + iPhone flasher

Following week…

- Learn the software to analyze light curve
- Figure out accurate time stamping on all videos
- Submit reports

Problems encountered 1…

- Cell phones have variable frame rates
- QHY required a frame update that was problematic
- EVScope Raw Video
- Timestamps on video are only accurate to 1 second
- 50-200ms best case for phone
- Poor video
- Compression
- Saturation
- Timing

Problems encountered 2…

- Software is complex
- Best hardware setup
- Extensive help
- I would forget for next time (took notes)
- Difficult to get right / high anxiety
- Expensive hardware for single use

Results

- Impacts quality of scientific data
- Data is being collected, no direct feedback, errors persist
- Missed opportunities
- Barrier to adoption
- Analog is going away
- Timebase accuracy

Wish list

- Something cheap and easy to repair
- Double duty
- Make more, share with friends
- Does the heavy lifting
- Switchable Cameras ($50 USD)
- Like ASI Air / Nina / Stellarmate / AstroBerry
- Global Shutter
- Accurate Timing
- Single unit, connect via wireless

Wish list - 2

- Public Outreach (hook up external display)
- Build your own camera (ideal for beginners for being “vested”)
- Easy, consistent, QA

Astrid (ASTro Imaging Device) - 1

- Single Unit (Raspberry Pi 4 + Camera + Timestamping)
- Plugs straight into the eyepiece or can be attached to a DSLR lens
- Wireless connection (VNC, possible iPhone app later)
- Occultations or Astrophotography
- OTERecorder app designed for occultations
- OTEStamper Board (only needed for occultations)
- Global Shutter

Astrid (ASTro Imaging Device) - 2

- Highly accurate timing (Frame pulse and LED)
- Written in Python
- Open Source
- 12V DC Supply (Lithium, Lead Acid)
- Switchable Camera Sensors
- Occultations or Astrophotography
- Mono or Color

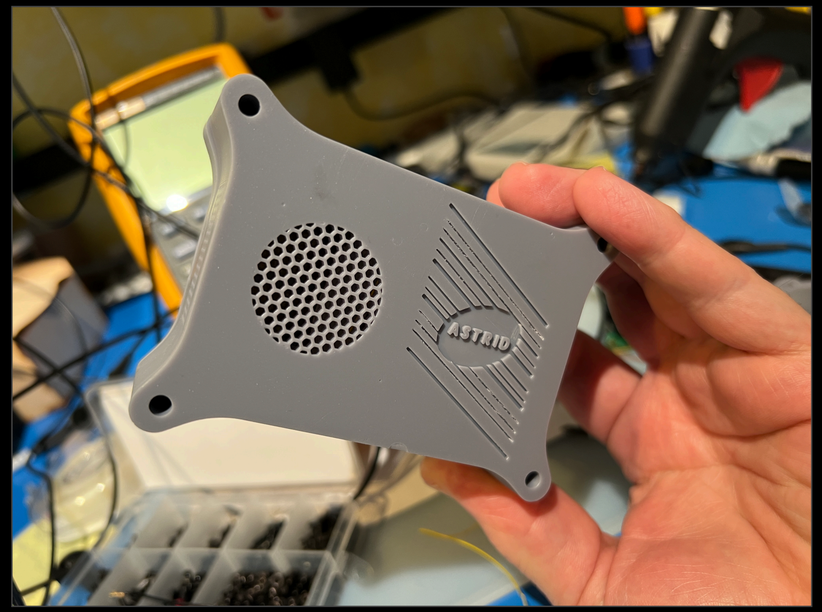
Astrid (ASTro Imaging Device) - 3

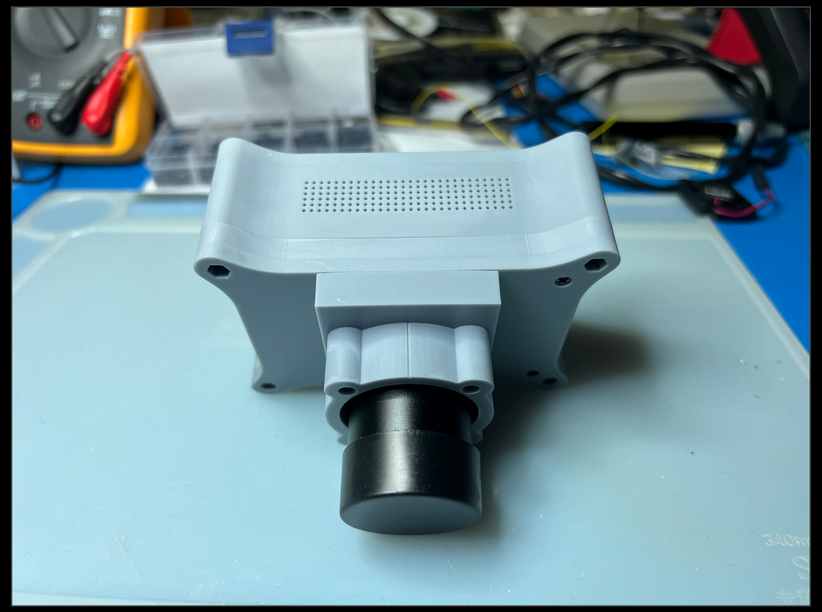
- Goto
- Plate Solving
- Polar Alignment
- Designed for the Task
- Automation, Planning
- Download Occultations
- Reduce User Error
- Audit Trail

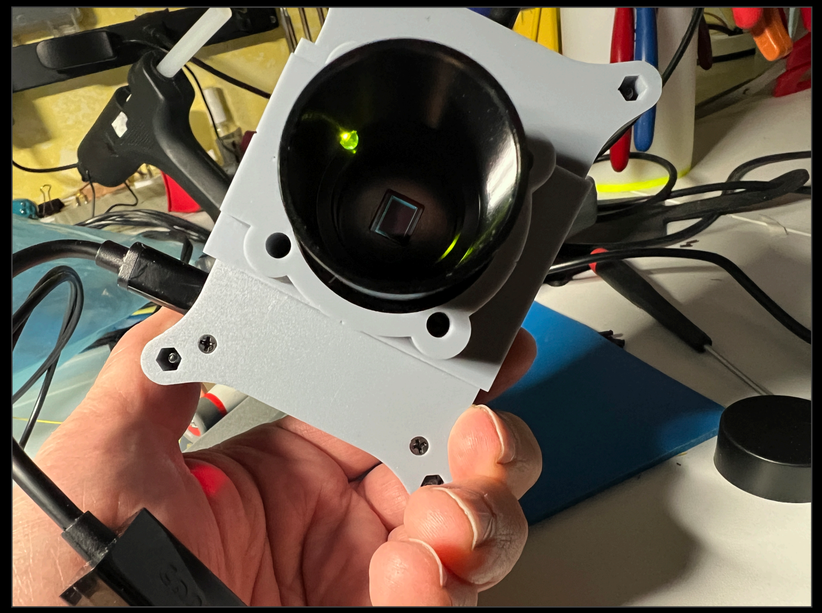
Astrid (ASTro Imaging Device) - 4

- Raw Data (no compression)
- Frame Triggered
- Saturation Detection
- Custom File Format: RAVF (AVD on spec update)

Astrid

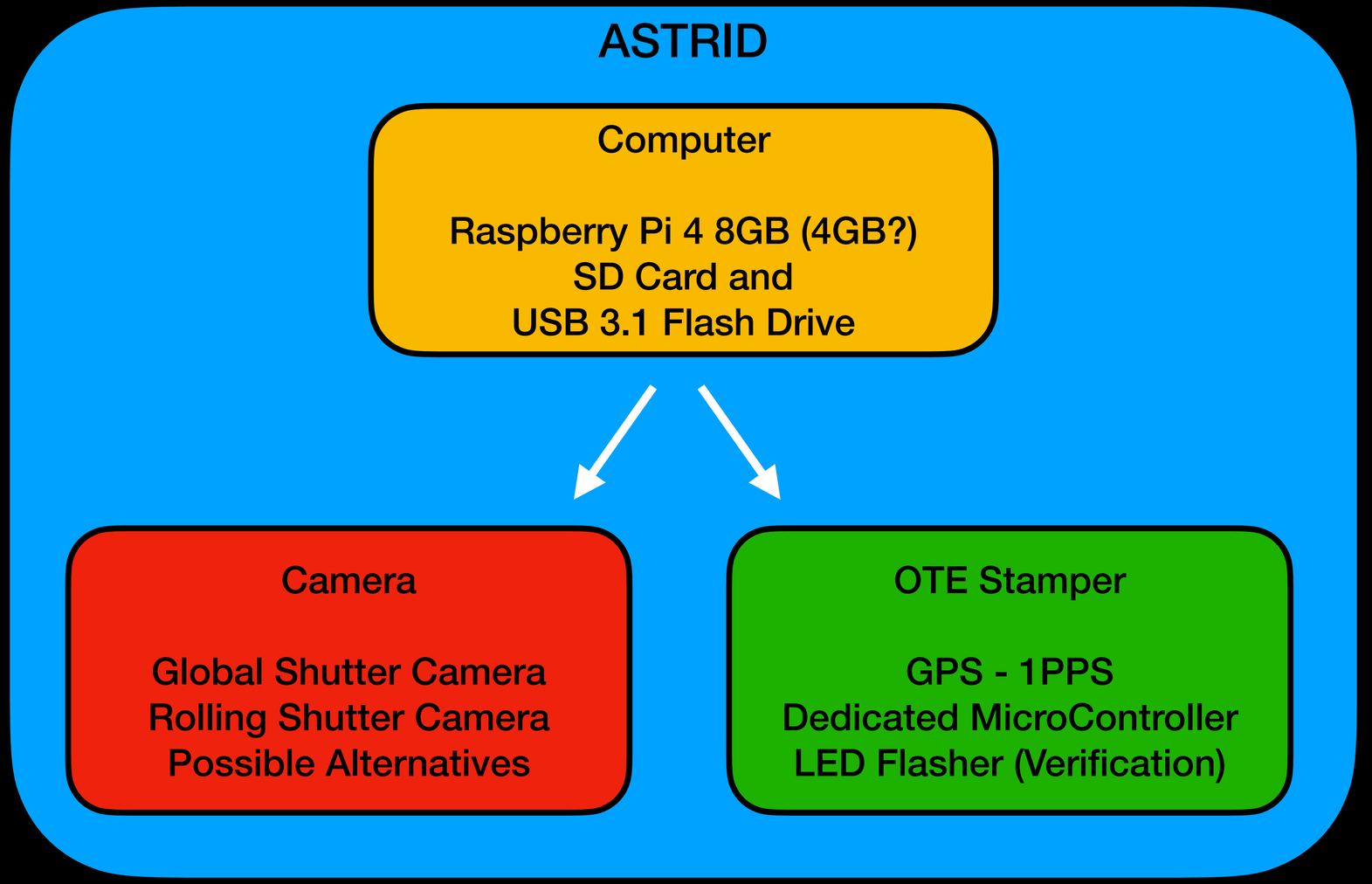




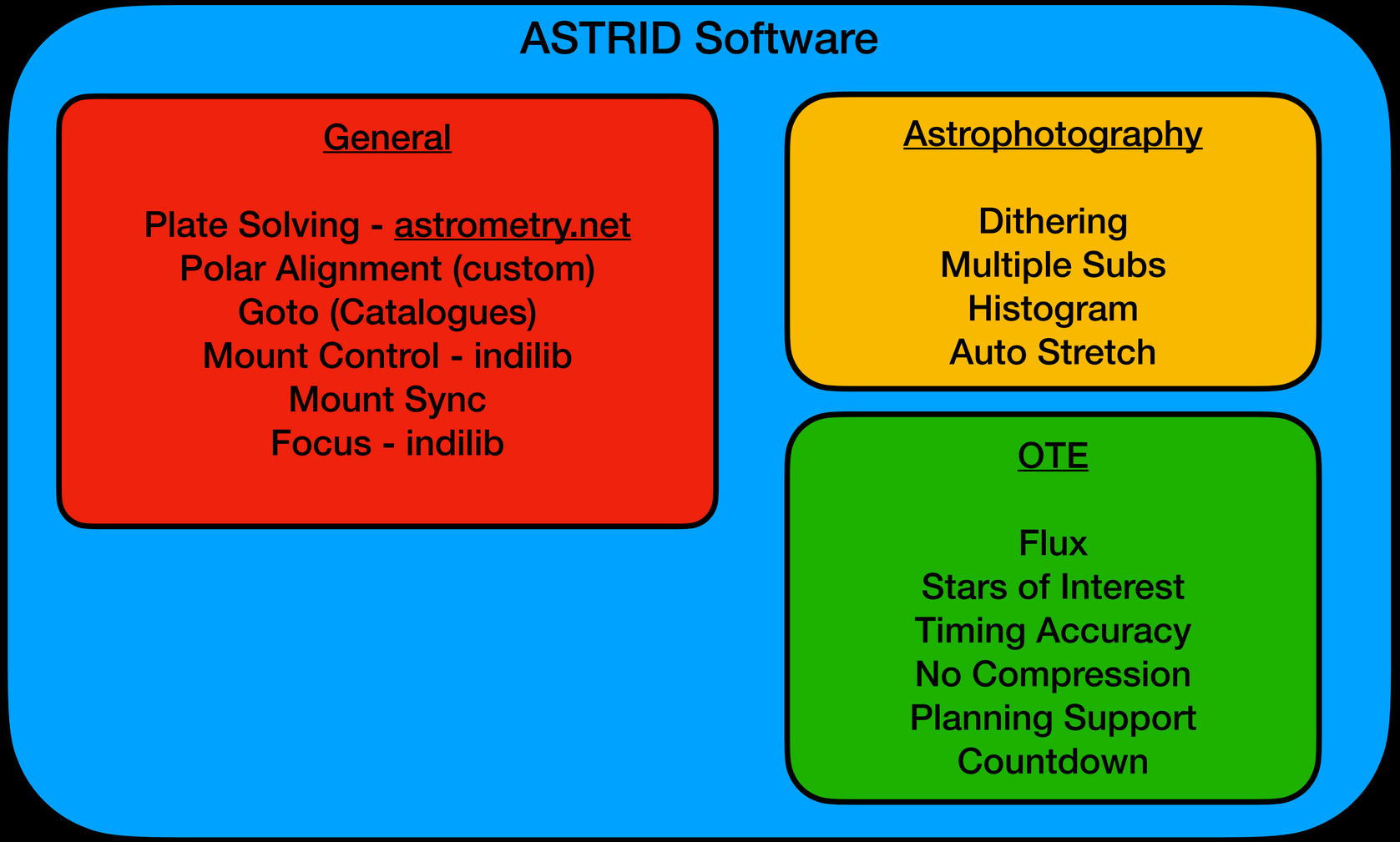


Astrid

Astrid Overview



Software Overview



Camera Sensor - Which Sensor?

Note - Categorization: Starvis and Starvis 2 are Backside Illuminated technologies (BSI). Starvis 2 has improved low-light performance due to larger pixel size.

ASI Model	Type	Status	Device Interface	V4L Support	Price	Sensor	Purchase	Technology	BSI	Sensor Interface	Datasheet	Manufacturer	Color	Shutter	Sensor Size	ADC Bits	Resolution	QE	Read Noise
Raspberry Pi GSC			CSI-2	Y	$50.00	IMX296LQR-C		Pregius Gen 2	N	CSI-2	https://scientif	Sony	Color	Global	5.023x3.754	10	1456x1088	68%	2.2e
same but mono			CSI-2	Y	$85.00	IMX296	https://ww	Pregius Gen 2	N		https://www.m	Sony	Mono	Global	5.023x3.754	10	1456x1088	68%	2.2e
Raspberry Pi HQ			CSI-2	Y	$60.00	IMX477R		Exmor RS	Y	CSI-2	https://www.u	Sony	Color	Rolling	6.287x4.712	12	4056x3040	?	1.5e
same but debayered by MaxMax			CSI-2	Y	$661.25	IMX477		Exmor RS	Y		https://maxma	Sony	Mono	Rolling	6.287x4.712	12	4056x3040	?	1.5e
Arducam OV9281			CSI-2	Y	$41.99	OV9281	https://www.arducam.com/product/ov9281-mipi-			CSI-2	https://www.o	Omnivision	Mono	Global	3.896x2.453	10	1280x800	High	
Maxmax Debayered IMX219 - Pi V2 Camera			CSI-2	Y	$570.00	IMX219		Exmor R	Y	CSI-2	https://maxma	Sony			5.095x4.930		3296x2512		
Arducam IMX378 - Built in Lens			CSI-2	Y		IMX378		Exmor RS		CSI-2		Sony	Color		6.286x4.712	10/12	4056x3040		
Raspberry Pi Camera Module 3 - Built in Lens			CSI-2	Y		IMX708		?		CSI-2		Sony	Color		6.451x3.628	10	4608x2592		
ASI220MM Mini	Guidecam		USB	N		SC2210		?	?			Sony	Mono	Rolling	7.58x4.32	12	1920x1080	92%	0.6-3.2e
ASI120MM Mini	Guidecam	Obsolete	USB	N		AR0130CS		?	?	Parallel	https://www.d	On Semiconductor	Mono	Rolling	4.8x3.6mm	12	1280x960	80%	4.0e
ASI174MM Mini	Guidecam		USB	N		IMX174LLJ		Pregius Gen 1	N	LVDS	https://www.s	Sony	Mono	Global	11.3x7.1	12	1936x1216	77%	3.5e
ASI462MM	Planetary		USB	N		IMX462LQR1		Starvis Gen 1	Y	LVDS/CSI-2	https://www.d	Sony	Mono	Rolling	5.6x3.2	12	1936x1096	89%	0.47e
Arducam have a color version of the IMX462	Planetary		CSI-2	N		IMX462		Starvis Gen 1	Y	LVDS/CSI-2	https://www.d	Sony	Color	Rolling	5.6x3.2	12	1936x1096	89%	0.47e
ASI533MM	DSO		USB	N		IMX533CLK-D		Starvis Gen 1	Y	SLVS-EC	https://b811c5	Sony	Mono	Rolling	11.31x11.31	14	3008x3008	91%	1.0e
ASI432MM	DSO		USB	N		IMX432LLJ		Pregius Gen 3 ?	N	SLVS-EC	https://www.p	Sony	Mono	Global	14.5x9.95	12	1608x1004	79%	2.4e
ASI294MM	DSO		USB	N		IMX492LLJ		?	?	CSI-2/SLVS-EC	https://www.p	Sony	Mono	Rolling	19.1x13.0	12	4144x2822	90%	1.26e
ASI290MM	Planetary		USB	N		IMX290LQR		Starvis Gen 1	Y	CSI-2/LVDS	https://www.g	Sony	Mono	Rolling	5.6x3.2	12	1936x1096	80%	1.0e
Arducam have a presale on a color version of the 290			CSI-2	N		IMX290		Starvis Gen 1	Y		https://www.g	Sony	Color	Rolling	5.6x3.2	12	1936x1096	80%	1.0e
Vision components via Mouser, 290 above			CSI-2	N	283.43 CAD	IMX290		Starvis Gen 1	Y		https://www.m	Sony	Mono	Rolling	5.6x3.2	12	1936x1096	80%	1.0e
ASI178MM	DSO		USB	N		IMX178LLJ-C		Starvis Gen 1	Y	CSI-2	https://s1-dl.th	Sony	Mono	Rolling	7.5x5.0	14	3096x2080	81%	1.4e
ASI183GT/ASI183MM	DSO		USB	N		IMX183CLK		Starvis Gen 1	Y		https://www.s	Sony	Mono	Rolling	13.2x8.8	12	5496x3672	84%	1.6e
Vision Components			CSI-2	N	Not on mouser	IMX183		Starvis Gen 1	Y		https://www.1	Sony	Mono	Rolling	13.2x8.8	12	5496x3672	84%	1.6e
ASI1600GT/ASI1600MM	DSO	EOL	CSI-2	N		MN34230				LVDS	https://mediap	Panasonic	Mono	?	17.7x13.4	12	3656x3520	60%	1.2e
Vision Components			CSI-2	N		IMX226		Starvis Gen 1	Y		https://www.1	Sony	Mono	Rolling	7.533x5.635	12	3840x3046	80%	
Vision Components			CSI-2	N	815.36 CAD	IMX252		Pregius Gen 2	N		https://www.1	Sony	Mono	Global	7.066x5.299	12	2048x1536	68%	2.3e
Vision Components			CSI-2	N	1232.67 CAD	IMX250		Pregius Gen 2			https://www.1	Sony	Mono	Global	8.446x7.066	12	2448x2048	68%	2.3e
Vision Components			CSI-2	N		IMX273		Pregius Gen 4			https://www.1	Sony	Mono	Global	4.970x3.726	12	1440x1080	64%	
			CSI-2	N		IMX415		Starvis Gen 1	Y		https://www.1	Sony	Mono	Rolling		12	3840x2160		

Camera Sensor - IMX296 LL (Mono)

README.md

- Global Shutter Camera

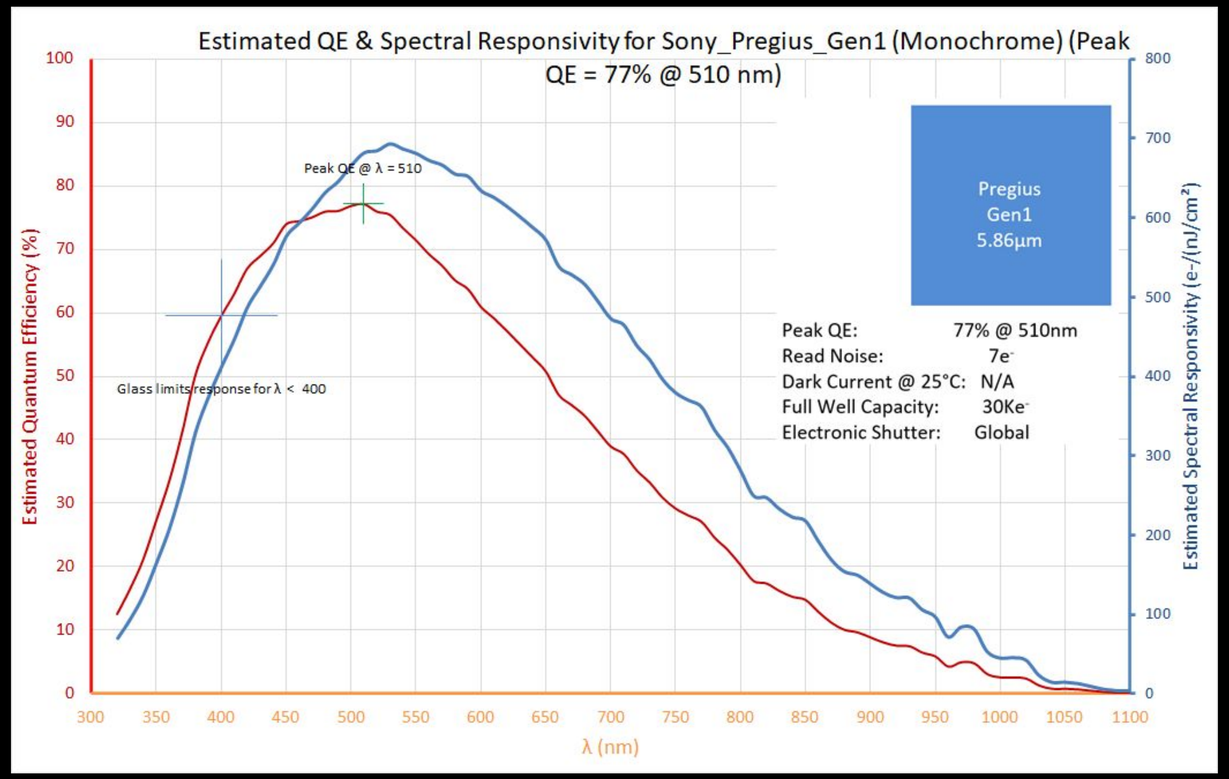
Name	Value
Sensor	Sony IMX296LQR-C Pregius Gen 2
Architecture	Front Illuminated
Mono/Color	Color
Shutter	Global
Pixel size	3.45um x 3.45um
Bits	RAW10
Sensor resolution	1456 x 1088 (1.58 Megapixels)
Sensor image area	5.023mm x 3.754mm
Sensor diagonal	6.3mm
Optical size	1/2.9"
Binning	1x
Dynamic range	TBD
Read noise	2.2e
Dark current @ 25C	3.2e/p/s
Full well capacity	10.6Ke
Quantum efficiency	Peak QR: 68% @ 550nm
Gain	1-16
Maximum exposure time	15.534385s
Minimum exposure time	29uS
IR cut filter	Yes - Removable, see "Filter Removal" Filter type unknown, but maybe Hoya CM500 i.e. same as HQ camera
Mode: 0	Size:(1456,1088) Bin:1 Bits:10 FOV:(100%,100%) MaxFPS:60.38 Exp:29us->15.534385s

Camera Sensor - Versus IMX174

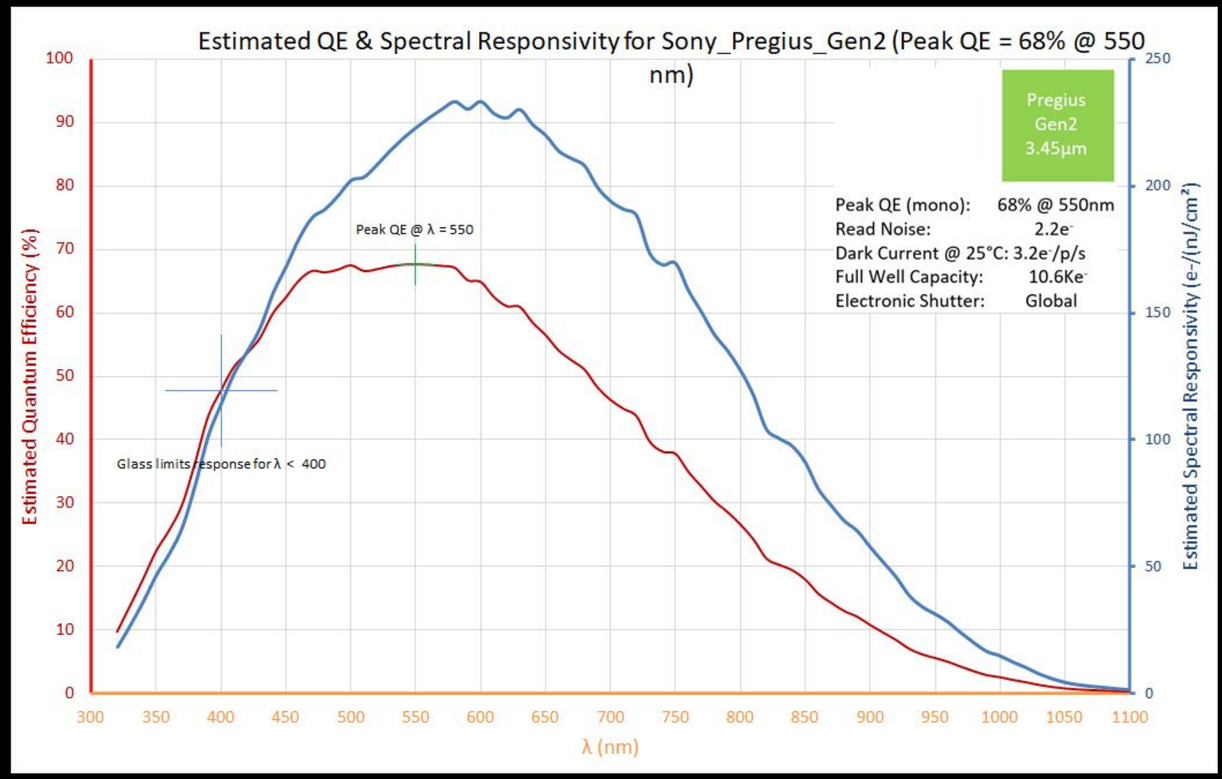
ASI Model	Sensor	Purchase	Technology	BSI	Sensor Interface	Datasheet	Manufacturer	Color	Shutter	Sensor Size	ADC Bits	Resolution	QE	Read Noise	Pixel Size	Fps
Raspberry Pi GSC	IMX296LQR-C		Pregius Gen 2	N	CSI-2	https://scientif	Sony	Color	Global	5.023x3.754	10	1456x1088	68%	2.2e	3.45um	60.38
same but mono	IMX296	https://ww	Pregius Gen 2	N		https://www.m	Sony	Mono	Global	5.023x3.754	10	1456x1088	68%	2.2e	3.45um	60.38
Raspberry Pi HQ	IMX477R		Exmor RS	Y	CSI-2	https://www.u	Sony	Color	Rolling	6.287x4.712	12	4056x3040	?	1.5e	1.55um	120.5
same but debayered by MaxMax	IMX477		Exmor RS	Y		https://maxma	Sony	Mono	Rolling	6.287x4.712	12	4056x3040	?	1.5e	1.55um	120.5
Arducam OV9281	OV9281	https://www.arducam.com/product/ov9281-mipi-			CSI-2	https://www.o	Omnivision	Mono	Global	3.896x2.453	10	1280x800	High		3um	120fps
Maxmax Debayered IMX219 - Pi V2 Camera	IMX219		Exmor R	Y	CSI-2	https://maxma	Sony			5.095x4.930		3296x2512			1.12um	180fps
Arducam IMX378 - Built in Lens	IMX378		Exmor RS		CSI-2		Sony	Color		6.286x4.712	10/12	4056x3040			1.55um	240fps
Raspberry Pi Camera Module 3 - Built in Lens	IMX708		?		CSI-2		Sony	Color		6.451x3.628	10	4608x2592			1.4um	
ASI220MM Mini	SC2210		?	?			Sony	Mono	Rolling	7.58x4.32	12	1920x1080	92%	0.6-3.2e	4um	14
ASI120MM Mini	AR0130CS		?	?	Parallel	https://www.d	On Semiconductor	Mono	Rolling	4.8x3.6mm	12	1280x960	80%	4.0e	3.75um	45
ASI174MM Mini	IMX174LLJ		Pregius Gen 1	N	LVDS	https://www.s	Sony	Mono	Global	11.3x7.1	12	1936x1216	77%	3.5e	5.86um	128.2
ASI462MM	IMX462LQR1		Starvis Gen 1	Y	LVDS/CSI-2	https://www.d	Sony	Mono	Rolling	5.6x3.2	12	1936x1096	89%	0.47e	2.9um	120

Camera Sensor - The QE Trap

Pregius Gen 1
IMX174 QHY GPS



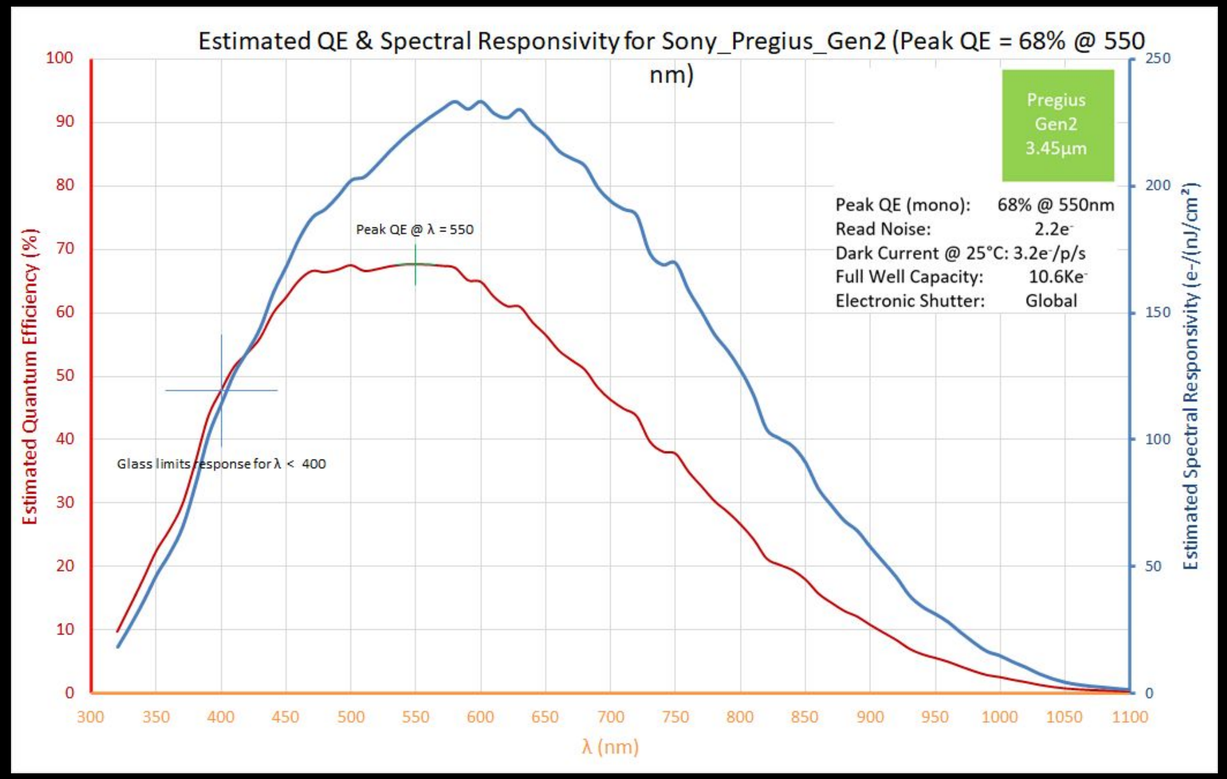
Pregius Gen 2
IMX296 - ASTRID



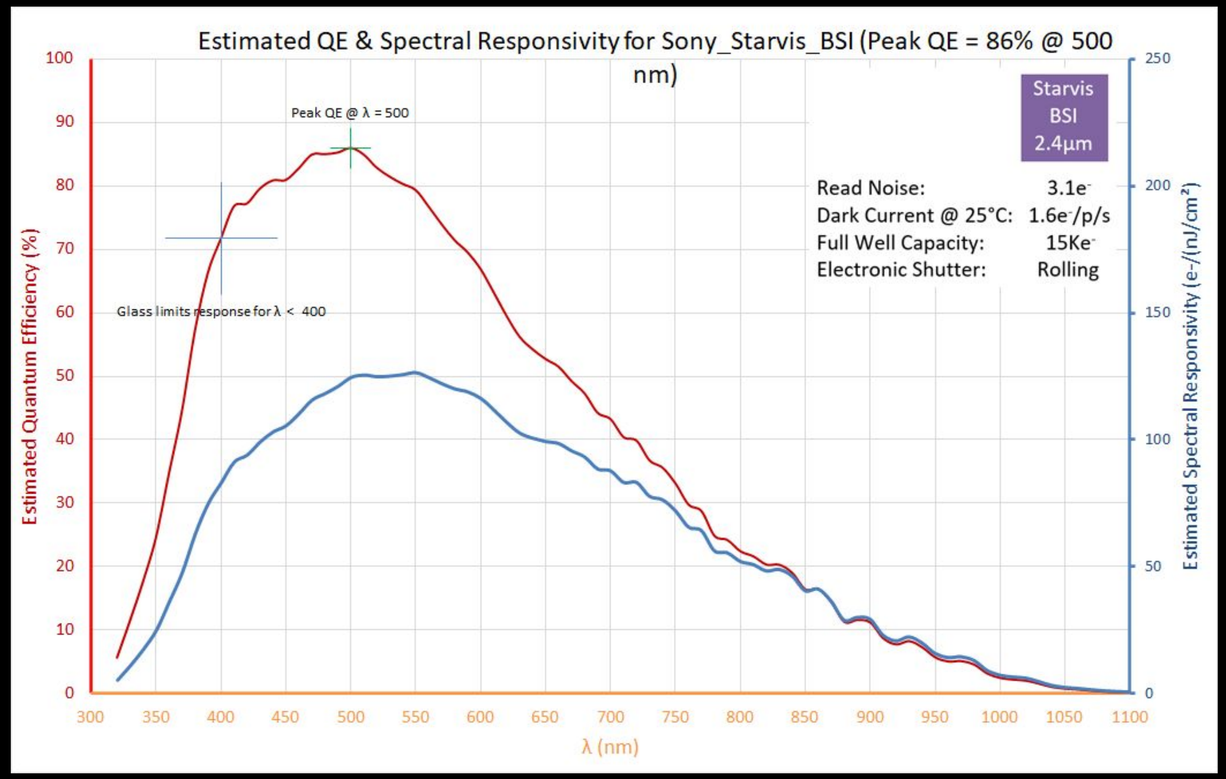
Source: https://scientificimaging.com/knowledge-base/quantum-efficiency-and-spectral-responsivity-of-scmos-and-cmos-imagers/

Camera Sensor - Starvis

Pregius Gen 2
IMX296 - ASTRID



Starvis



Source: https://scientificimaging.com/knowledge-base/quantum-efficiency-and-spectral-responsivity-of-scmos-and-cmos-imagers/

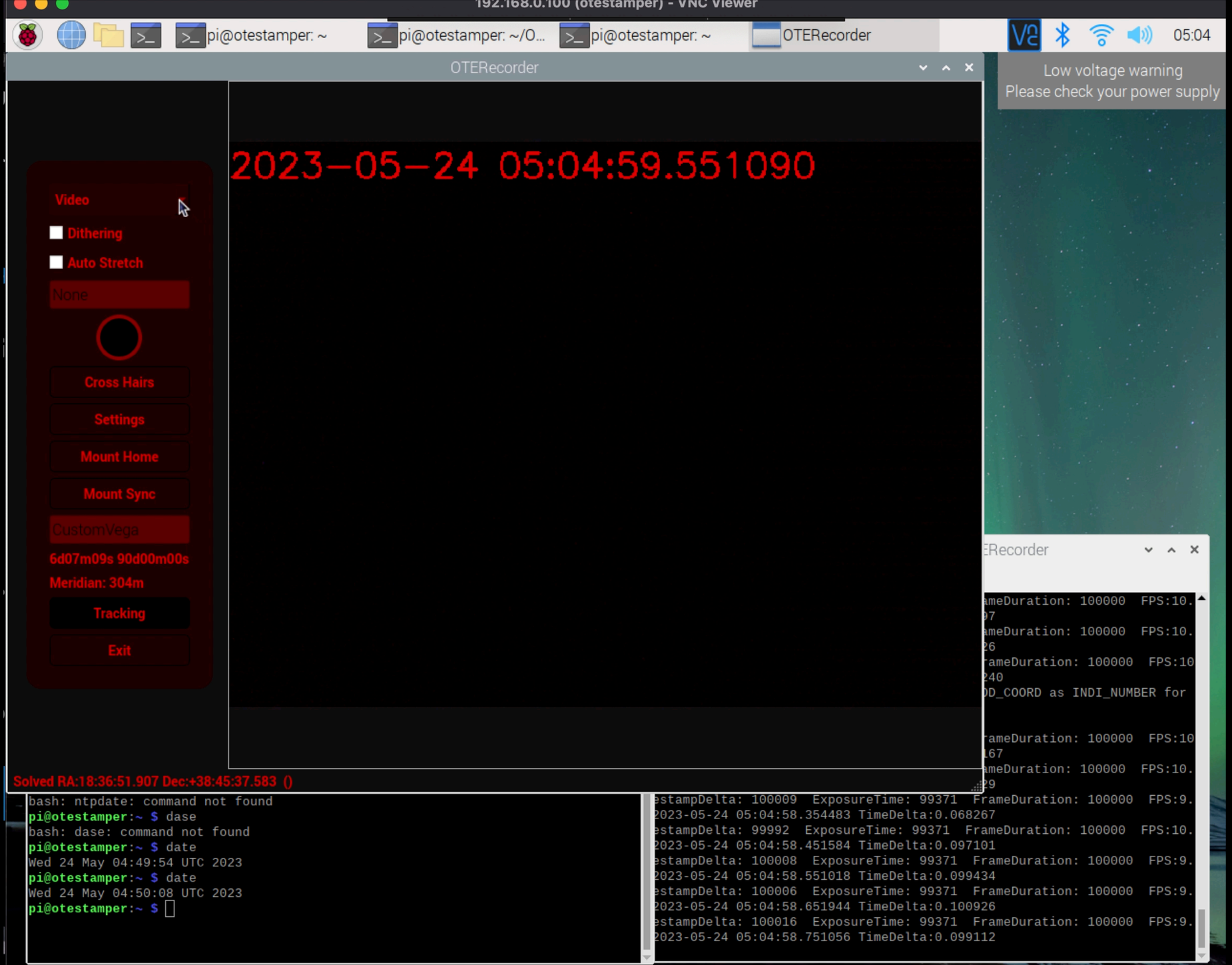
Current status

- Talking to AM5 mount and NexStar SE (newer)
- Plate solving
- Polar Alignment
- Goto
- Meridian Flip
- Occultations
- Astrophotography
- Firmware for OTEStamper (GPS, LED, Frame Trigger)

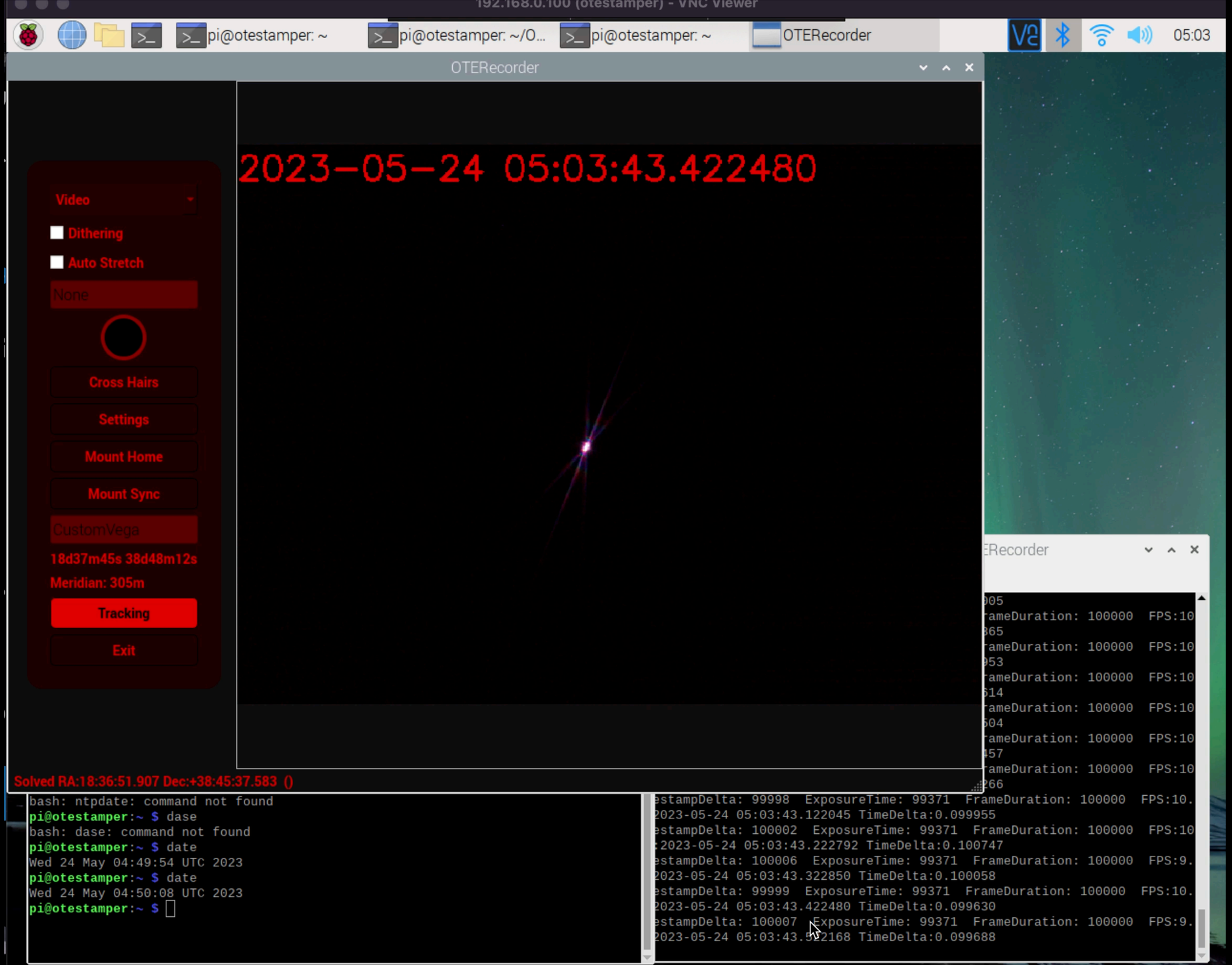
Testing so far

- 1 Occultation
- M101, Elephant Trunk, M3, M81
- Global Shutter and Rolling Shutter
- Polar Alignment, Plate Solving, Goto work
- Minimal User Interface Currently
- 6 OTEStamper Boards Built

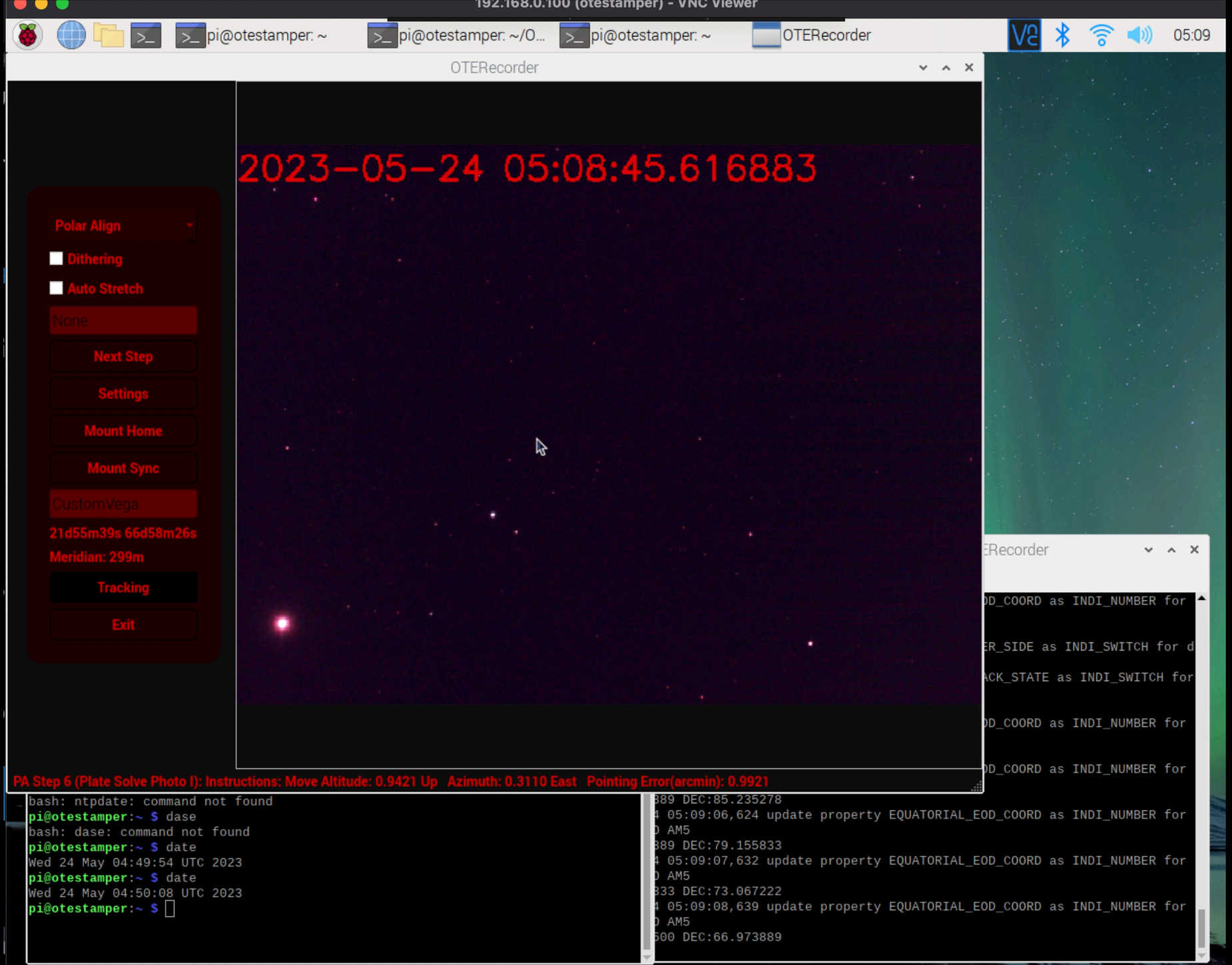
Polar Alignment



Focus


192.168.0.100 (otestamper) - VNC Viewer
pi@otestamper: ~
pi@otestamper: ~/O...
pi@otestamper: ~
OTERecorder
05:03
OTERecorder
2023-05-24 05:03:43.422480
Video
Dithering
Auto Stretch
None
Cross Hairs
Settings
Mount Home
Mount Sync
CustomVega
18d37m45s 38d48m12s
Meridian: 305m
Tracking
Exit
Solved RA:18:36:51.907 Dec:+38:45:37.583 ()
bash: ntpdate: command not found
pi@otestamper:~ $ dase
bash: dase: command not found
pi@otestamper:~ $ date
Wed 24 May 04:49:54 UTC 2023
pi@otestamper:~ $ date
Wed 24 May 04:50:08 UTC 2023
pi@otestamper:~ $
ERecorder
FrameDuration: 100000 FPS:10
FrameDuration: 100000 FPS:10
FrameDuration: 100000 FPS:10
FrameDuration: 100000 FPS:10
FrameDuration: 100000 FPS:10
FrameDuration: 100000 FPS:10
estampDelta: 99998 ExposureTime: 99371 FrameDuration: 100000 FPS:10.
2023-05-24 05:03:43.122045 TimeDelta:0.099955
estampDelta: 100002 ExposureTime: 99371 FrameDuration: 100000 FPS:10
2023-05-24 05:03:43.222792 TimeDelta:0.100747
estampDelta: 100006 ExposureTime: 99371 FrameDuration: 100000 FPS:9.
2023-05-24 05:03:43.322850 TimeDelta:0.100058
estampDelta: 99999 ExposureTime: 99371 FrameDuration: 100000 FPS:10.
2023-05-24 05:03:43.422480 TimeDelta:0.099630
estampDelta: 100007 ExposureTime: 99371 FrameDuration: 100000 FPS:9.
2023-05-24 05:03:43.522168 TimeDelta:0.099688

Goto - Vega


192.168.0.100 (otestamper) - VNC Viewer
pi@otestamper: ~
pi@otestamper: ~/O...
pi@otestamper: ~
OTERecorder
05:09
OTERecorder
2023-05-24 05:08:45.616883
Polar Align
Dithering
Auto Stretch
None
Next Step
Settings
Mount Home
Mount Sync
CustomVega
21d55m39s 66d58m26s
Meridian: 299m
Tracking
Exit
PA Step 6 (Plate Solve Photo I): Instructions: Move Altitude: 0.9421 Up Azimuth: 0.3110 East Pointing Error(arcmin): 0.9921
bash: ntpdate: command not found
pi@otestamper:~ $ dase
bash: dase: command not found
pi@otestamper:~ $ date
Wed 24 May 04:49:54 UTC 2023
pi@otestamper:~ $ date
Wed 24 May 04:50:08 UTC 2023
pi@otestamper:~ $
ERecorder
OD_COORD as INDI_NUMBER for
ER_SIDE as INDI_SWITCH for d
ACK_STATE as INDI_SWITCH for
OD_COORD as INDI_NUMBER for
OD_COORD as INDI_NUMBER for
389 DEC:85.235278
4 05:09:06,624 update property EQUATORIAL_EOD_COORD as INDI_NUMBER for
D AM5
389 DEC:79.155833
4 05:09:07,632 update property EQUATORIAL_EOD_COORD as INDI_NUMBER for
D AM5
333 DEC:73.067222
4 05:09:08,639 update property EQUATORIAL_EOD_COORD as INDI_NUMBER for
D AM5
500 DEC:66.973889

Occultation - (1337) Gerada - 10.7 Mag 3.3s

OW Cloud (1337) Gerada occults TYC 5211-00516-1 on 2023-Jun-07 at 10:00 UT

Light Theme | Welcome, ChasinSpin

Closest Approach	Rank	Asteroid		Star	Mag	Comb.	Drop	Max Dur
2023-Jun-07, 10:00 UT	90	(1337) Gerada (16.3 m)		TYC 5211-00516-1 (10.71 m) [RUWE: 1.35] Star Chart: 15° 5° 2° 0.5° 0.1°	10.7 m	10.7 m	5.6 m	4.35 sec

Predictions

Data Sources	Last Updated (UT)	Orbit Date	Error (PW *)	Error (time)	Path Diff **
Horizons/GaiaEDR3 default	26 Apr, 12:38 (by OWC)	24 Apr 2023 (JPL#79)	0.54	4.2 sec	-
	21 Apr, 07:01 (by SteveP)	25 Nov 2022	15.04	1:04 min	+13 m

* PW = path widths; ** Across and along path difference between predictions. Across path shift is computed on the Fundamental Plane, where '-' indicates a left and '+' a right path shift.

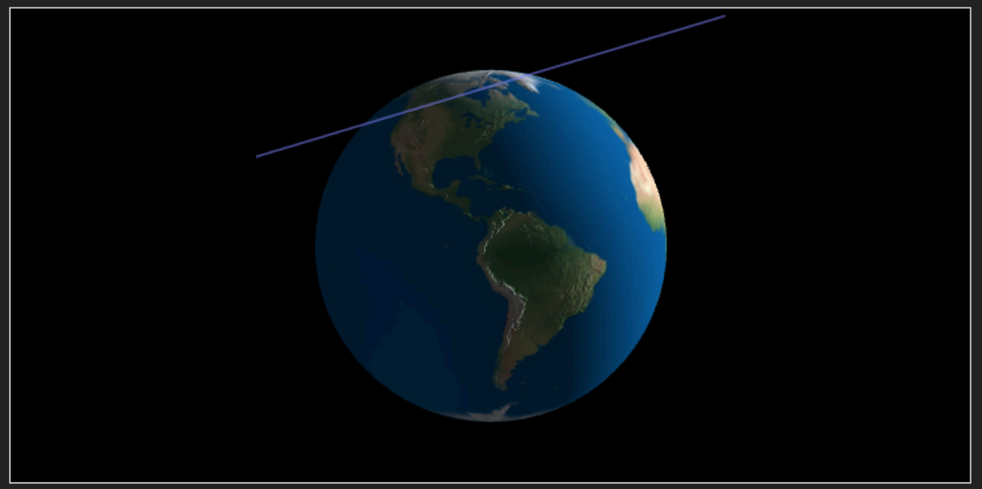
Countries in 1-σ Zone (3)

Canada Greenland United States of America

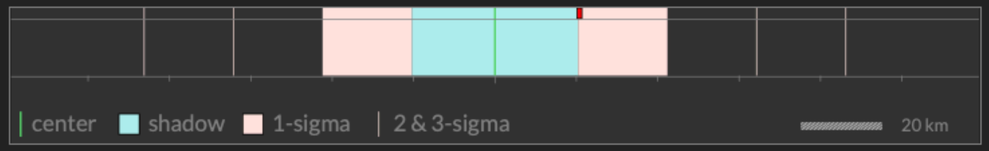
Tags (1)

IOTA

Tag Event



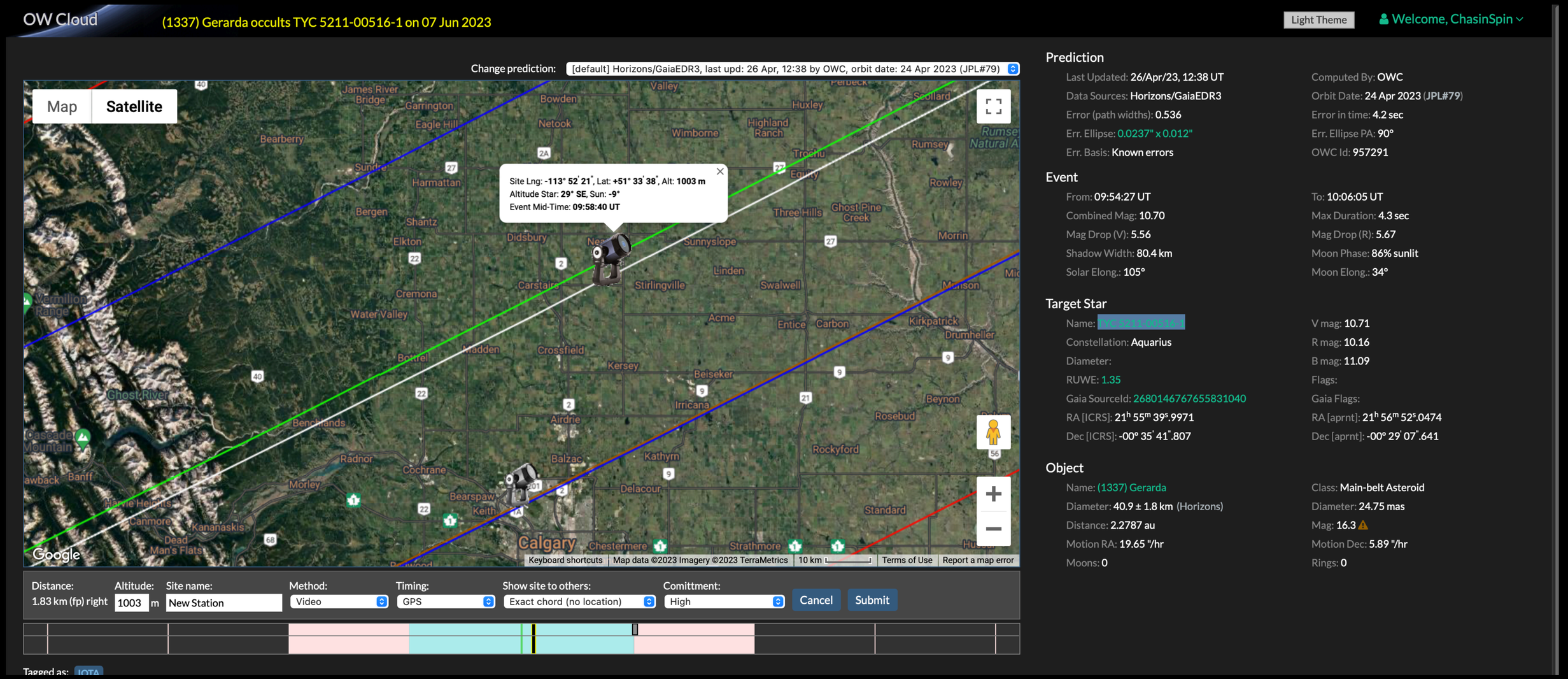
Shadow crossing the Earth for **11:37 min** from **09:54:27 UT** to **10:06:05 UT**



Stations (1)

Chord	Observer	Note
20.2 km	G Schmidt	Observed a miss

Occultation - (1337) Gerada - 10.7 Mag 3.3s



Prediction

- Last Updated: 26/Apr/23, 12:38 UT
- Computed By: OWC
- Data Sources: Horizons/GaiaEDR3
- Orbit Date: 24 Apr 2023 (JPL#79)
- Error (path widths): 0.536
- Error in time: 4.2 sec
- Err. Ellipse: 0.0237" x 0.012"
- Err. Ellipse PA: 90°
- Err. Basis: Known errors
- OWC Id: 957291

Event

- From: 09:54:27 UT
- To: 10:06:05 UT
- Combined Mag: 10.70
- Max Duration: 4.3 sec
- Mag Drop (V): 5.56
- Mag Drop (R): 5.67
- Shadow Width: 80.4 km
- Moon Phase: 86% sunlit
- Solar Elong.: 105°
- Moon Elong.: 34°

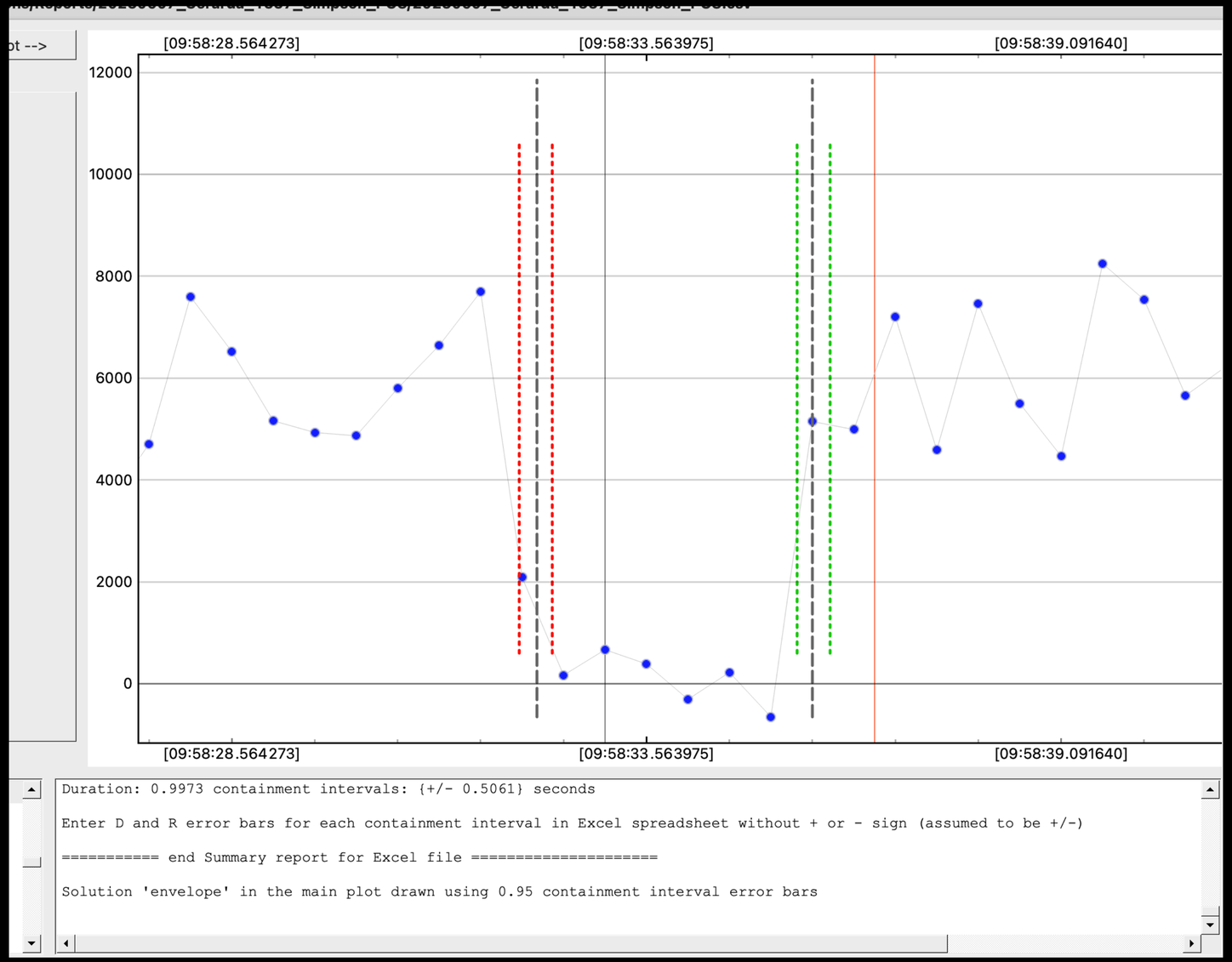
Target Star

- Name: TYC 5211-00516-1
- V mag: 10.71
- Constellation: Aquarius
- R mag: 10.16
- Diameter:
- B mag: 11.09
- RUWE: 1.35
- Flags:
- Gaia SourceId: 2680146767655831040
- Gaia Flags:
- RA [ICRS]: $21^h\ 55^m\ 39^s.9971$
- RA [aprnt]: $21^h\ 56^m\ 52^s.0474$
- Dec [ICRS]: -00° 35' 41".807
- Dec [aprnt]: -00° 29' 07".641

Object

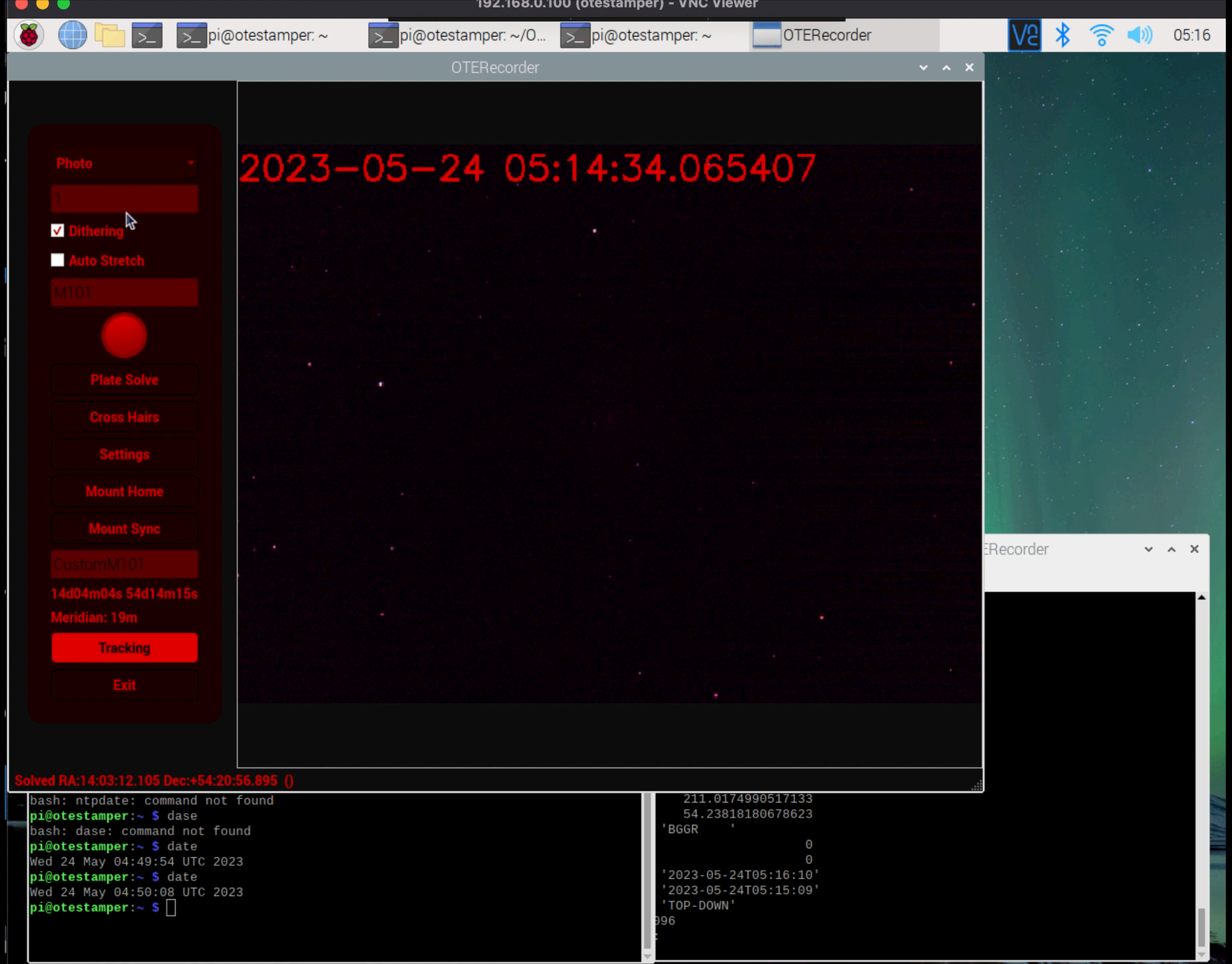
- Name: (1337) Gerada
- Class: Main-belt Asteroid
- Diameter: 40.9 ± 1.8 km (Horizons)
- Diameter: 24.75 mas
- Distance: 2.2787 au
- Mag: 16.3
- Motion RA: 19.65 "/hr
- Motion Dec: 5.89 "/hr
- Moons: 0
- Rings: 0

Light Curve


[09:58:28.564273]
[09:58:33.563975]
[09:58:39.091640]
12000
10000
8000
6000
4000
2000
0
[09:58:28.564273]
[09:58:33.563975]
[09:58:39.091640]
Duration: 0.9973 containment intervals: {+/- 0.5061} seconds
Enter D and R error bars for each containment interval in Excel spreadsheet without + or - sign (assumed to be +/-)
========== end Summary report for Excel file ==========
Solution 'envelope' in the main plot drawn using 0.95 containment interval error bars

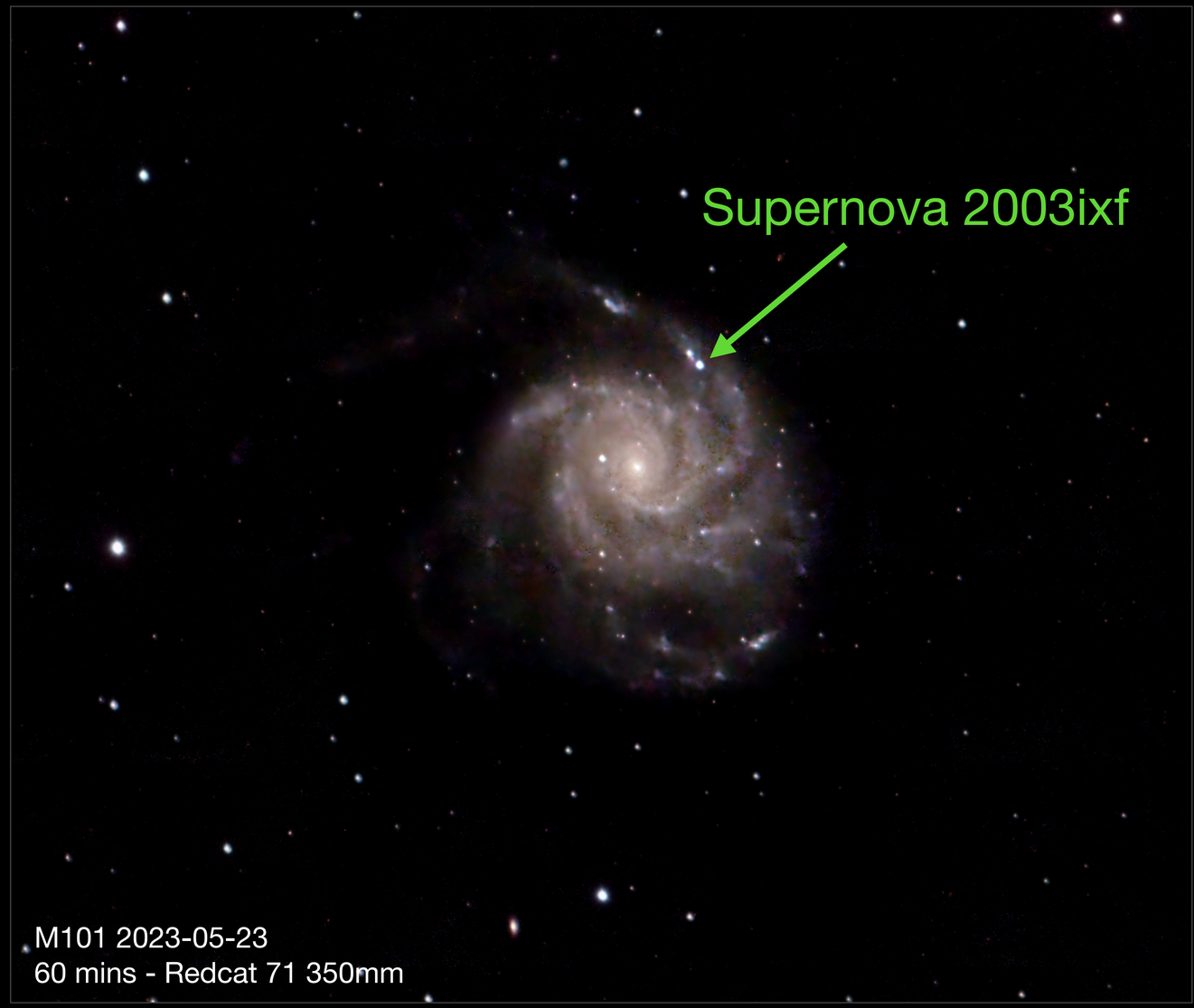
PyMovie Demo

Imaging


192.168.0.100 (otestamper) - VNC Viewer
pi@otestamper: ~
pi@otestamper: ~/O...
pi@otestamper: ~
OTERecorder
05:16
OTERecorder
Photo
1
Dithering
Auto Stretch
M101
Plate Solve
Cross Hairs
Settings
Mount Home
Mount Sync
CustomM101
14d04m04s 54d14m15s
Meridian: 19m
Tracking
Exit
2023-05-24 05:14:34.065407
Solved RA:14:03:12.105 Dec:+54:20:56.895 ()
bash: ntpdate: command not found
pi@otestamper:~ $ dase
bash: dase: command not found
pi@otestamper:~ $ date
Wed 24 May 04:49:54 UTC 2023
pi@otestamper:~ $ date
Wed 24 May 04:50:08 UTC 2023
pi@otestamper:~ $
211.0174990517133
54.23818180678623
'BGGR '
0
0
'2023-05-24T05:16:10'
'2023-05-24T05:15:09'
'TOP-DOWN'
ERecorder

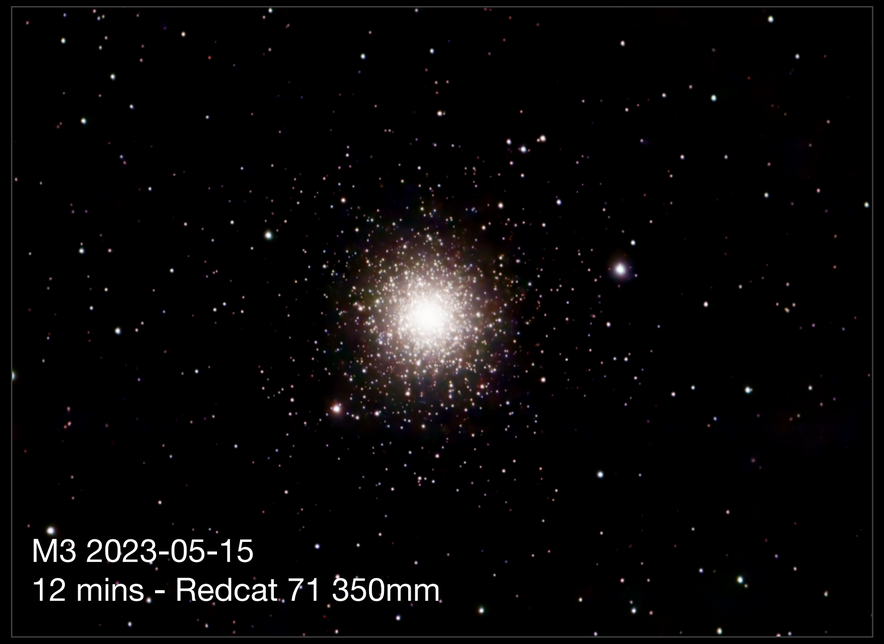
HQ Camera (Rolling Shutter)

Elephant Trunk Nebula 2023-05-23
30 mins - Redcat 71 350mm

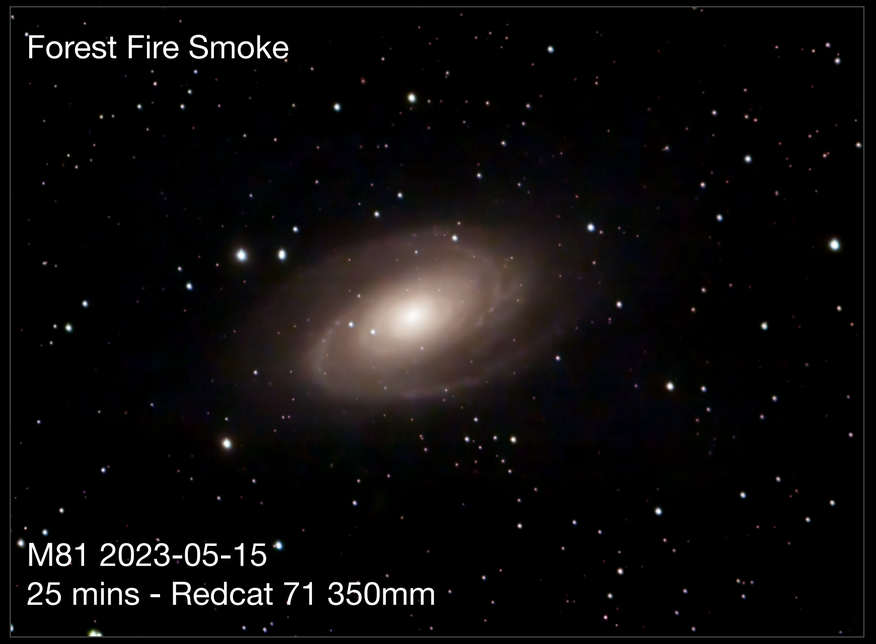


M101 2023-05-23
60 mins - Redcat 71 350mm

GS Camera (Global Shutter)



M3 2023-05-15
12 mins.- Redcat 71 350mm



Forest Fire Smoke

M81 2023-05-15
25 mins - Redcat 71 350mm

Forest Fire Smoke

M101 2023-05-15
12 mins - Redcat 71 350mm

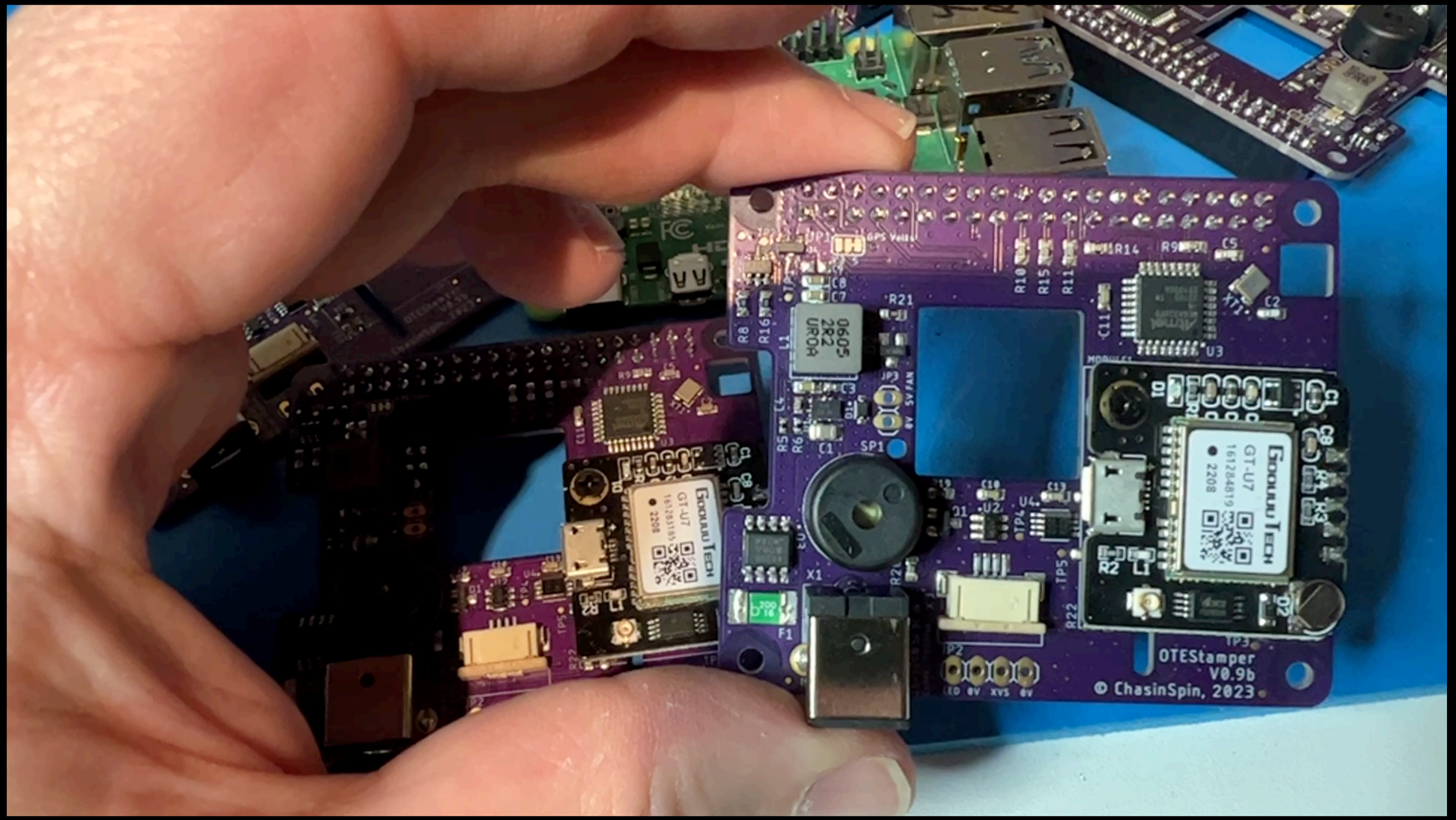
Forest Fire Smoke

Elephant Trunk Nebula 2023-05-15
17 mins - Redcat 71 350mm

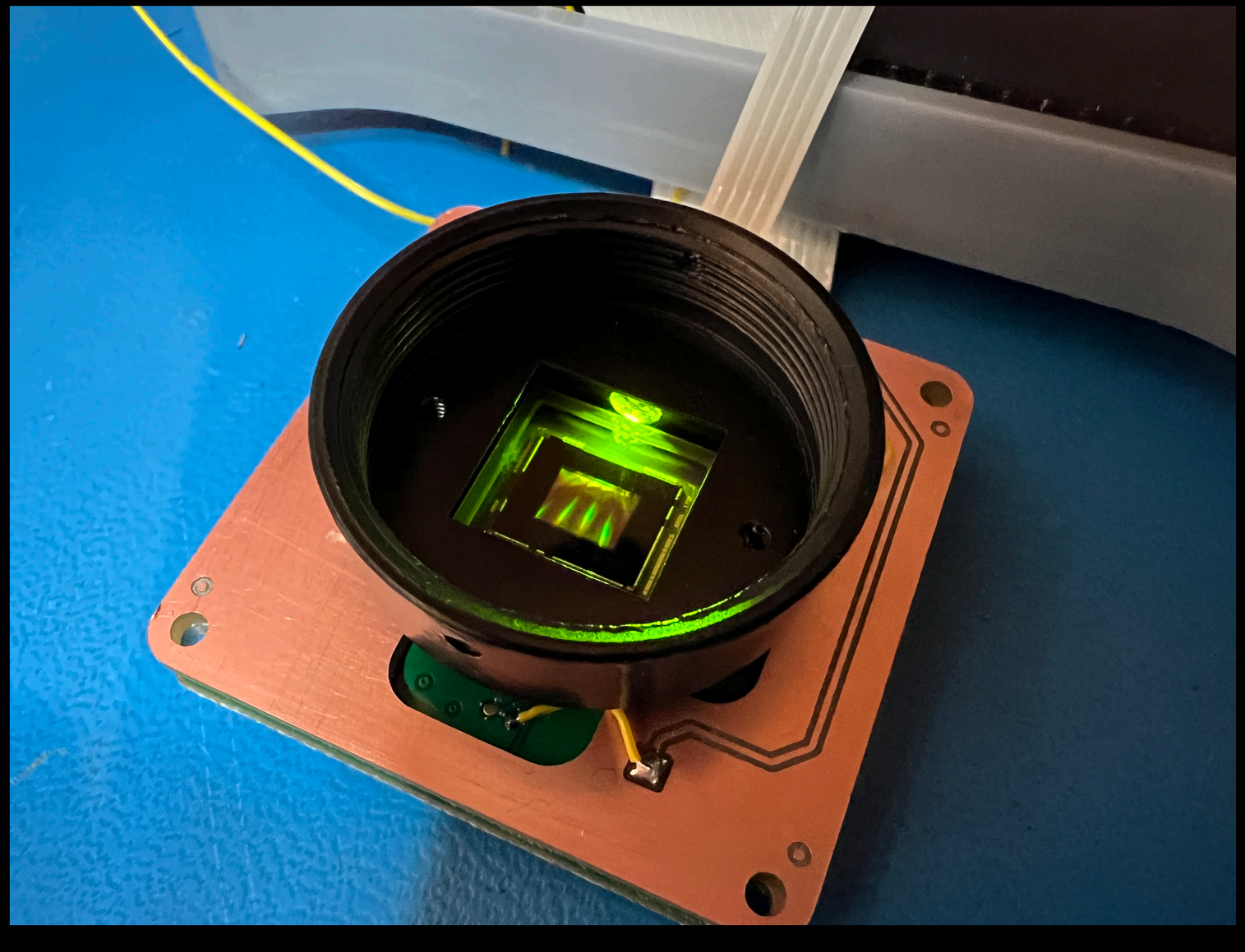
OTEStamper

- GPS with PPS
- LED (next to sensor)
- Frame Trigger - 40.3ns
- Timestamp accuracy - 1.25us
- Forgiving 12V DC Power supply (reverse polarity protection)
- Switchable fan (vibration)
- Easy no cable firmware updates via Raspberry Pi

OTEStamper

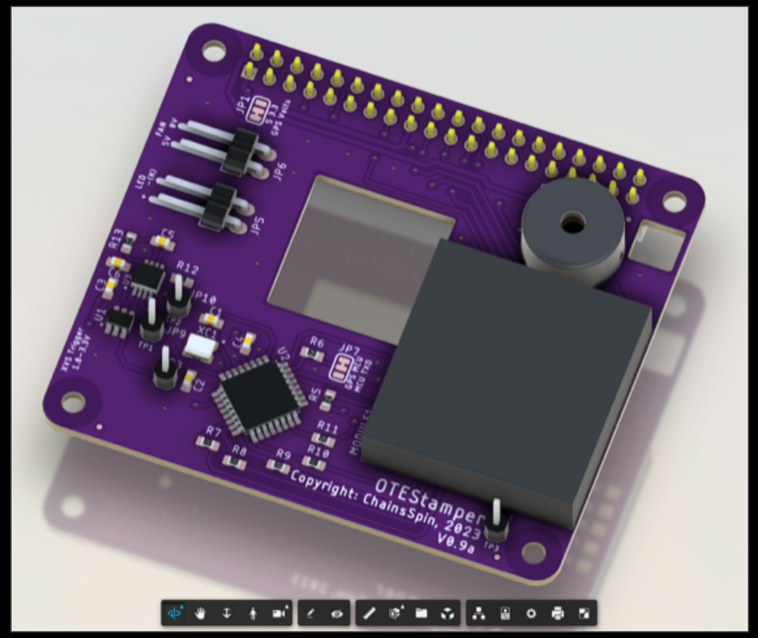


OTEStamper - LED (Timing Verification)

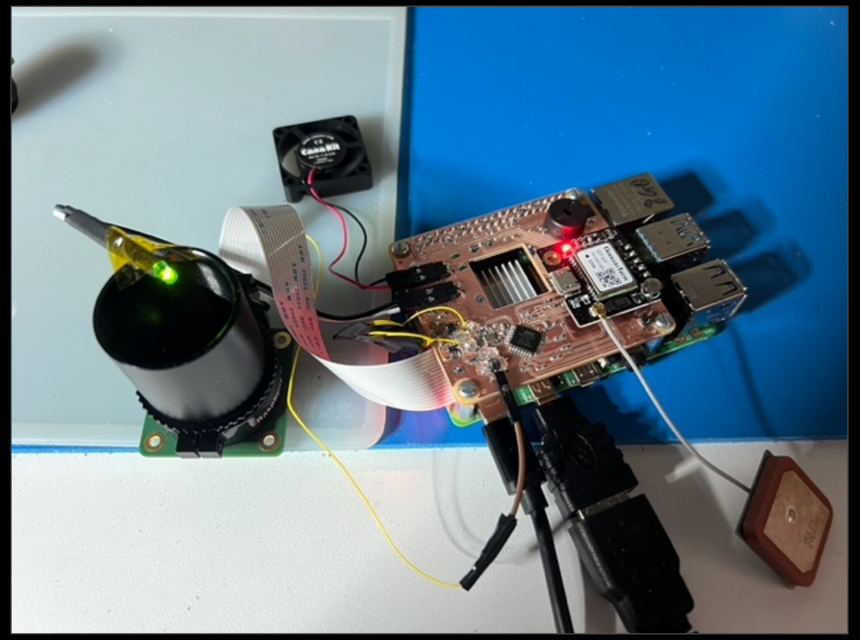


OTEStamper

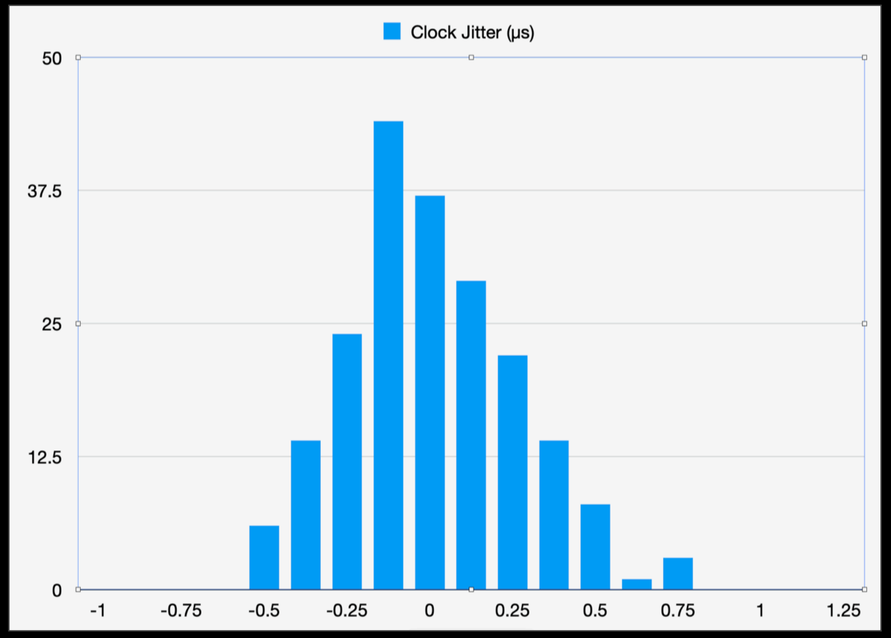
Prototype 3D Render



CNC’d Prototype

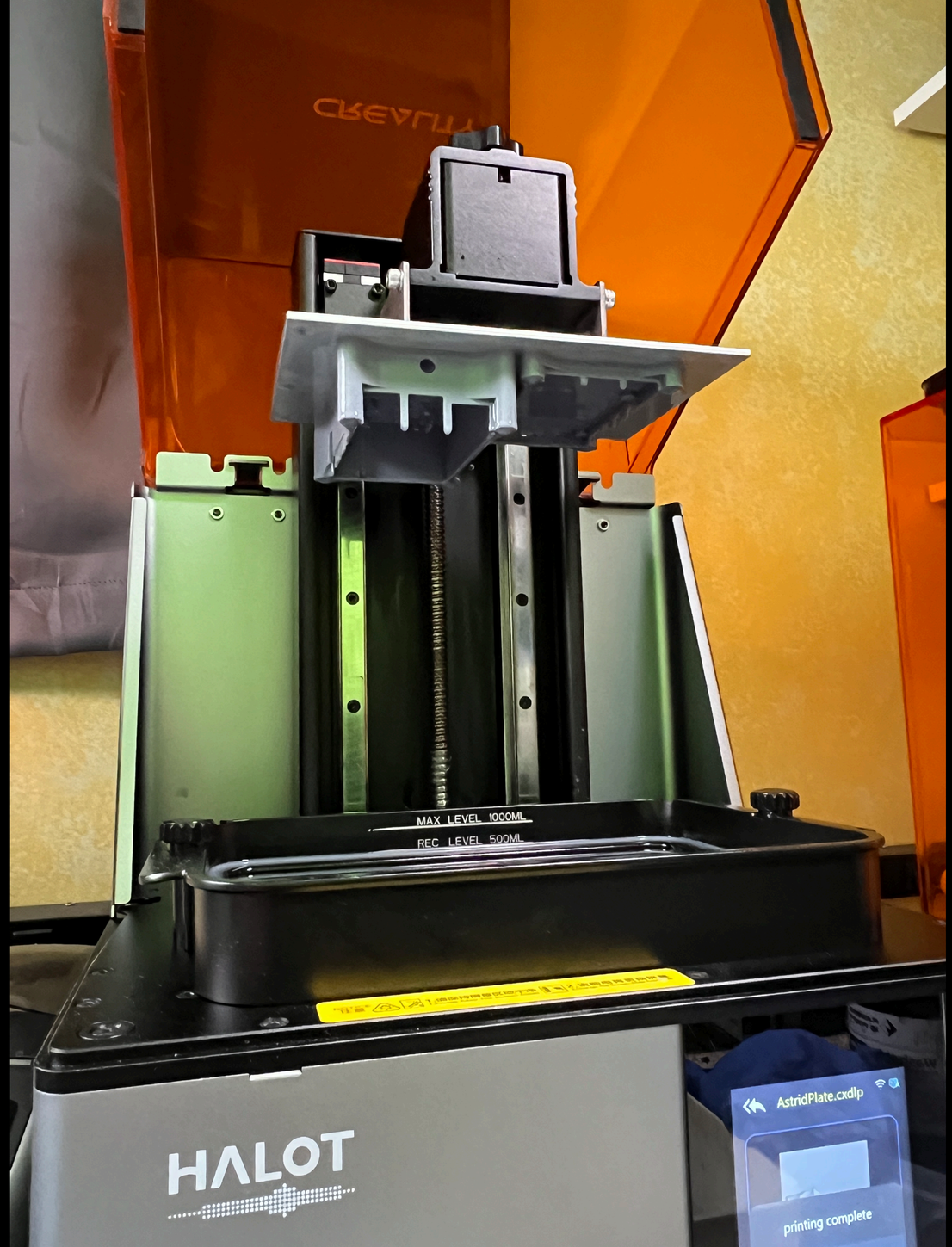


Timing Jitter Testing



Case

- 3D Printed
- Other options (Hyperstar)



Astrid Live Demo

Status

Current

- 6 Boards Built (4 allocated) - Steve Preston, Bill Yeung, Testing x 2
- Occultations Working
- General Astrophotography Working

Future Work

- Development In Progress
- User Interface Improvement
- More Mounts

Thanks

- Steve Preston
- Bob Anderson
- Hristo Pavlov

Questions / Contact

Mark Simpson

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