

# Progress and Future Plans for emCCD Testing

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**33<sup>rd</sup> Annual Meeting of the International  
Occultation Timing Association**

16-18 October July 2015

Cheyenne Campus of the College of Southern Nevada

North Las Vegas, Nevada

# Agenda

- Testing performed this past year
- New hardware acquired and access to new facilities
- Plans for testing in the coming year

# emCCD Cameras

- Described in our 2014 IOTA talk:  
**“Specialized Software and Equipment for High Speed Cameras”**



Photometrics Cascade 512B emCCD



CCD read noise is reduced from 10's of electrons per pixel to under 0.1 per pixel. Back illumination increases QE to over 90%.

# 2015 Testing to Date

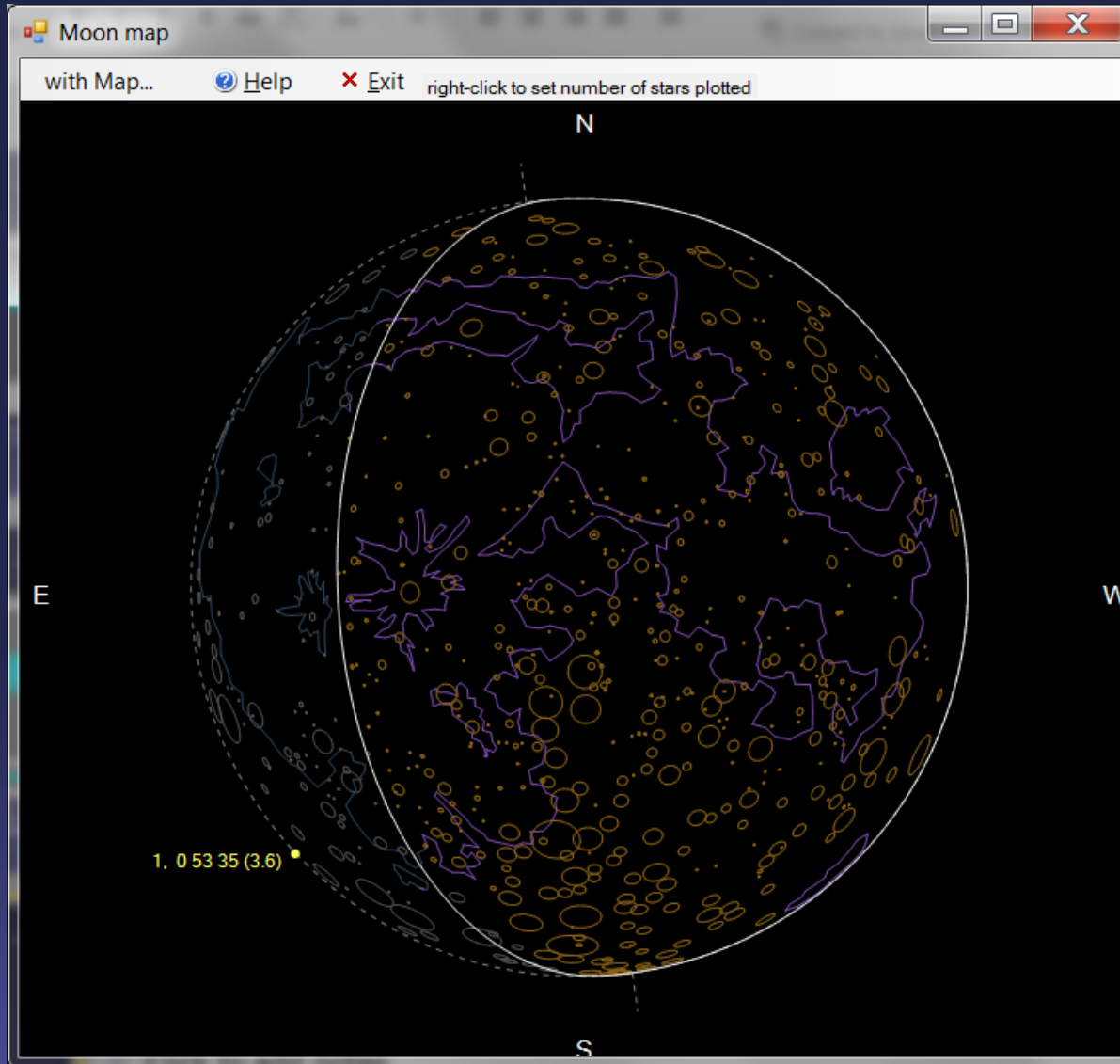
- Due to work commitments, only a very limited amount of testing was performed
- A few lunar occultations were attempted
  - Lambda Gemini is the only one we'll address today
- No appropriate asteroid events were tried
  - On high probability events, we tend to be risk adverse, and avoid losing a potential positive by using traditional equipment
  - New equipment and access to new facilities should help with this in the coming year

# Lambda Gemini

- On Feb 28<sup>th</sup>, the waxing gibbous moon occulted  $\lambda$ -Gemini over North America
  - This is (quadruple) star, with non-instantaneous transitions reported
- Conard used a Photometrics 512B, on a C-14 operating at its native f:11 to attempt to record this event
  - The camera was windowed at 32 x 32, and binned by 2, in order to achieve a frame rate of 200 Hz
  - Dylan's software (PVCAMTest and Bin2ADV) was used to record & convert the data, and Tangra used for the analysis

# Lambda Gem Moon Map at Willow Oak Observatory

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# Lambda Gem Occultation at Willow Oak Observatory



Lunar occultation predictions

with Prediction ... Set Output filter Mag limit adjustment... Weather forecasts... Help Exit

1. Select site for predictions: Use home, BDH sites2.site, Set home, Steve Conard, Use single, Filter search to sites

2. Star cat.: XZ, XZ < mag, XZ < mag, XZ < mag, ZC

3. Stars, Planets, Asteroids, Grazes or Doubles

4. Set IIT dates: Year, Month, Day, Starting at, End, Year, Month, Day, Today

5. Events for: Occultations, Short Output, Apply Filter

6. Events anywhere: Graze, Multi-site, World map

Right-click on prediction for further options [2015 Feb 28]

Occultation prediction for Steve Conard  
 E. Longitude - 77 52 0.0, Latitude 39 20 0.0, Alt. 210m; Telescope dia 50cm; dMag 0.0

day	Time	P	Star	Sp	Mag	Mag	%	Elon	Sun	Moon	CA	PA	VA	AA	Libration	A	B	RV	Cct	durn	R.A. (J2000)	Dec	Mdist	SV									
y	m	d	h	m	s	No	D	v	r	V	ill	Alt	Alt	Az	o	o	o	o	L	B	m/o	m/o	"/s	o	sec	h	m	s	o	m	s	Mm	m/s
15	Feb	28	23	48	17	d	X	99797	9.7	9.2	81+	128	-10	54	120	86S	97	142	90	+5.9	+7.0	+1.9+0.6	.346	-2.1	7	16	49.9	16	43	23	394.5	670.5	
15	Mar	1	0	46	19	d		96738	9.4	9.0	81+	128	63	141	39S	144	175	137	+5.7	+7.0	+2.0-2.7	.226	-46.5	7	17	46.2	16	30	47	394.2	635.9		
15	Mar	1	0	53	35	D		1106SA3	3.6	3.5s	81+	128	64	144	50S	133	161	125	+5.7	+7.0	+2.1-1.8	.268	-34.8	7	18	5.6	16	32	25	394.2	633.2		
R1106 = lambda Geminorum 1106 is quadruple: ** 4.0 5.0 0.045" 300.0, dT = -0.16sec : AB 3.6 10.7 9.7" 34.1, dT = -6sec : AB 10.7" 258.9, dT = -23sec 1106 has been reported as non-instantaneous (OCc 502). Observations are highly desired 1106 = NSV 3512, 3.52 to 3.62, V																																	
15	Mar	1	1	9	25	D		96753cK0	8.5	7.7	81+	129	65	152	67S	117	139	109	+5.7	+7.0	+2.2-0.9	.309	-17.8	7	18	37.4	16	35	10	394.1	628.5		
96753 is double: ** 9.5 9.5 0.08" 96.0, dT = +0.24sec 96753 has been reported as non-instantaneous (OCc 989). Observations are highly desired																																	
15	Mar	1	2	11	2	R		1106SA3	3.6	3.5s	81+	129	67	189	-63S	247	239	239	+5.4	+7.0	+2.6+1.2	.266	-145.3	7	18	5.6	16	32	25	394.2	626.8		
R1106 = lambda Geminorum 1106 is quadruple: ** 4.0 5.0 0.045" 300.0, dT = -0.1sec : AB 3.6 10.7 9.7" 34.1, dT = +31sec : AB 10.7" 258.9, dT = -39sec 1106 has been reported as non-instantaneous (OCc 502). Observations are highly desired 1106 = NSV 3512, 3.52 to 3.62, V																																	
15	Mar	1	2	21	8	d		X100367	9.3	9.1	81+	129	67	194	57N	60	49	52	+5.4	+7.0	+2.7+1.6	.242	41.7	7	20	12.1	16	45	14	394.2	628.5		
15	Mar	1	2	33	2	d		X100423	9.8	9.2	81+	129	66	201	77S	106	90	98	+5.3	+7.0	+2.1-1.0	.325	-3.8	7	20	33.9	16	32	41	394.3	631.7		

# Lambda Gem – The System

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- Right ascension 07h 18m 05.6s
- Declination +16° 32' 25.4"
- Apparent magnitude (V) 3.571[2]
- Radius  $2.7773 \pm 0.0469 R_{\odot}$
- Distance  $30.9 \pm 0.2$  pc
  
- Quadruple

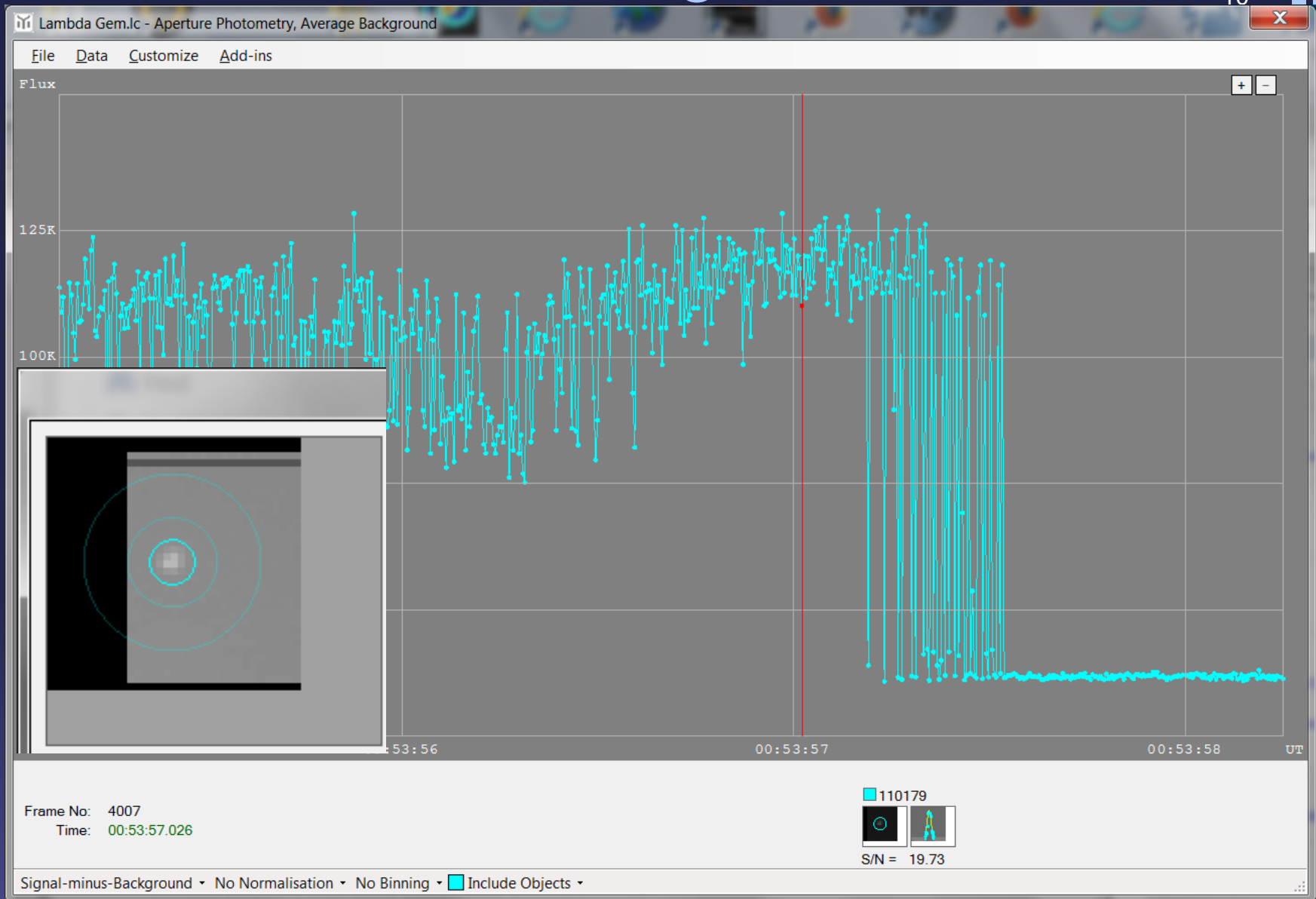
Source: Wikipedia



# Lambda Gem Video Using Media Player Classic

# Lambda Gem – Tangra LC

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# Computed Graze

Lunar occultation predictions

with Prediction ... Set Output filter Mag limit adjustment... Weather forecasts... Help Exit

1. Select site for predictions: Use home BDH sites2.site Set home -158.0 to -73.3, 17.7 to 42.1 Use single Steve Conard Filter search to sites i

2. Star cat.  XZ  XZ < mag  XZ < mag  XZ < mag  ZC

3.  Stars  Planets  Asteroids  Grazes or Doubles

4. Set LIT dates: Start Year Month Day Starting e Start 2015 Fe 20 -6 hrs End 2015 Fe 20 0 hrs +6 hrs +12hrs

5. Events for Occultations  Short Output  Apply Filter

6. Events anywhere Graze Multi-site World map

**Right-click on prediction for further options** [2015 Feb 28]

Grazing Occultation of 1106SA3 Magnitude 3.6 [Red = 3.5] s  
R1106 = lambda Geminorum  
Date: 2015 Mar 01 1h 26m, to 2015 Mar 01 1h 41m  
Nominal site altitude 210m

E. Longit.	Latitude	U.T.	Sun Alt	Moon Alt Az	TanZ	PA	AA	CA
o ' "	o ' "	h m s				o	o	o
- 81 0 0	32 20 18	1 25 58	72 146	0.33 189.5	181.53	-6.04S		
- 80 45 0	32 18 49	1 26 41	72 147	0.33 189.6	181.62	-6.13S		
- 80 30 0	32 17 17	1 27 25	72 148	0.32 189.7	181.71	-6.22S		
- 80 15 0	32 15 42	1 28 9	72 149	0.32 189.8	181.80	-6.31S		
- 80 0 0	32 14 4	1 28 53	72 150	0.32 189.8	181.88	-6.39S		
- 79 45 0	32 12 23	1 29 37	73 151	0.31 189.9	181.97	-6.48S		
- 79 30 0	32 10 39	1 30 21	73 153	0.31 190.0	182.06	-6.57S		
- 79 15 0	32 8 51	1 31 5	73 154	0.31 190.1	182.15	-6.66S		
- 79 0 0	32 7 1	1 31 49	73 155	0.30 190.2	182.24	-6.75S		
- 78 45 0	32 5 7	1 32 34	73 157	0.30 190.3	182.33	-6.84S		
- 78 30 0	32 3 10	1 33 18	74 158	0.29 190.4	182.42	-6.93S		
- 78 15 0	32 1 10	1 34 3	74 159	0.29 190.5	182.50	-7.02S		
- 78 0 0	31 59 7	1 34 47	74 161	0.29 190.6	182.59	-7.10S		
- 77 45 0	31 57 0	1 35 32	74 162	0.29 190.6	182.68	-7.19S		
- 77 30 0	31 54 51	1 36 17	74 163	0.28 190.7	182.77	-7.28S		
- 77 15 0	31 52 38	1 37 2	74 165	0.28 190.8	182.86	-7.37S		
- 77 0 0	31 50 22	1 37 47	74 166	0.28 190.9	182.95	-7.46S		
- 76 45 0	31 48 3	1 38 32	75 168	0.28 191.0	183.03	-7.55S		
- 76 30 0	31 45 41	1 39 17	75 170	0.27 191.1	183.12	-7.63S		
- 76 15 0	31 43 16	1 40 3	75 171	0.27 191.2	183.21	-7.72S		
- 76 0 0	31 40 47	1 40 48	75 173	0.27 191.3	183.30	-7.81S		

Path coordinates are referred to WGS84 (as used by GPS), with the nominal site altitude being referenced to Mean Sea Level. The path is adjusted for the effects of refraction at low moon altitudes.

Projected diameter of star 1 meters [CHARM/CADARS, 3 measures]

# Computed Graze was in Georgia

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The image is a screenshot of the Google Earth application. The main window displays a satellite-style map of the Eastern United States, including parts of Pennsylvania, New Jersey, Maryland, Virginia, North Carolina, South Carolina, and Georgia. A yellow path is overlaid on the map, starting near Lake Erie and following the Appalachian Mountains and Chesapeake Bay region. A blue line is drawn on the map, pointing from the bottom right towards the Georgia/South Carolina border. The left sidebar contains the 'Search' bar, 'Places' list (with 'LunarGrazePath.kmz' selected), and 'Layers' panel (with 'Primary Database' and 'Voyager New!' selected). The bottom of the window shows the 'Image Landsat' and 'Data SIO, NOAA, U.S. Navy, NGA, GEBCO' information, along with the 'Imagery Date: 4/9/2013' and 'eye alt 887.19 mi'.

Google Earth

File Edit View Tools Add Help

Search

ex: 37 25.818' N, 122 05.36' W

Get Directions History

Places

Temporary Places

LunarGrazePath.kmz

Graze of ZC1106 2015 Feb 29

Layers

Earth Gallery

Primary Database

Voyager New!

Borders and Labels

Places

Photos

Roads

3D Buildings

Ocean

Weather

Gallery

Global Awareness

More

Image Landsat

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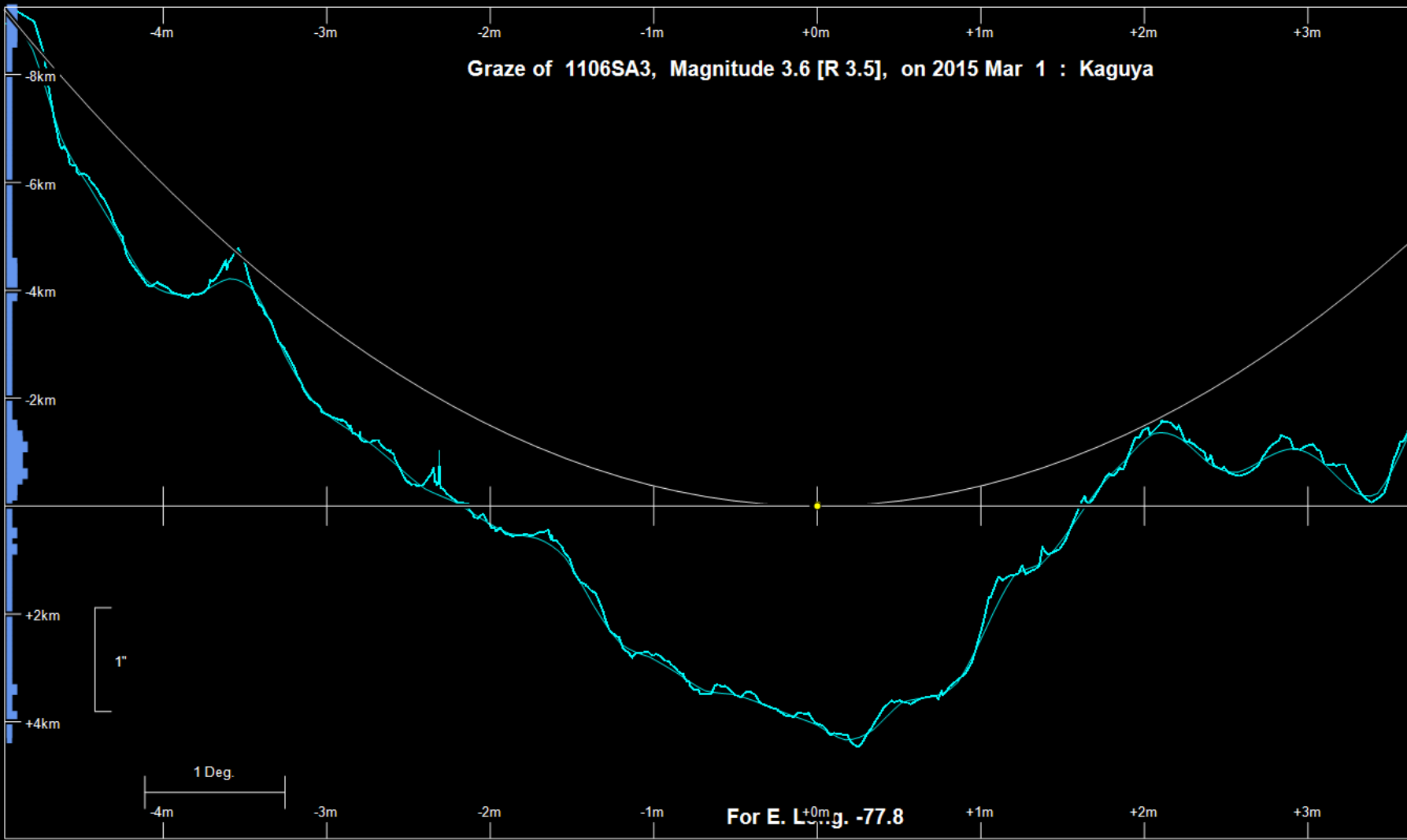
Data SIO, NOAA, U.S. Navy, NGA, GEBCO

Imagery Date: 4/9/2013 35°26'59.37" N 76°24'57.68" W elev -2 ft eye alt 887.19 mi

Google earth

Tour Guide

**Graze of 1106SA3, Magnitude 3.6 [R 3.5], on 2015 Mar 1 : Kaguya**

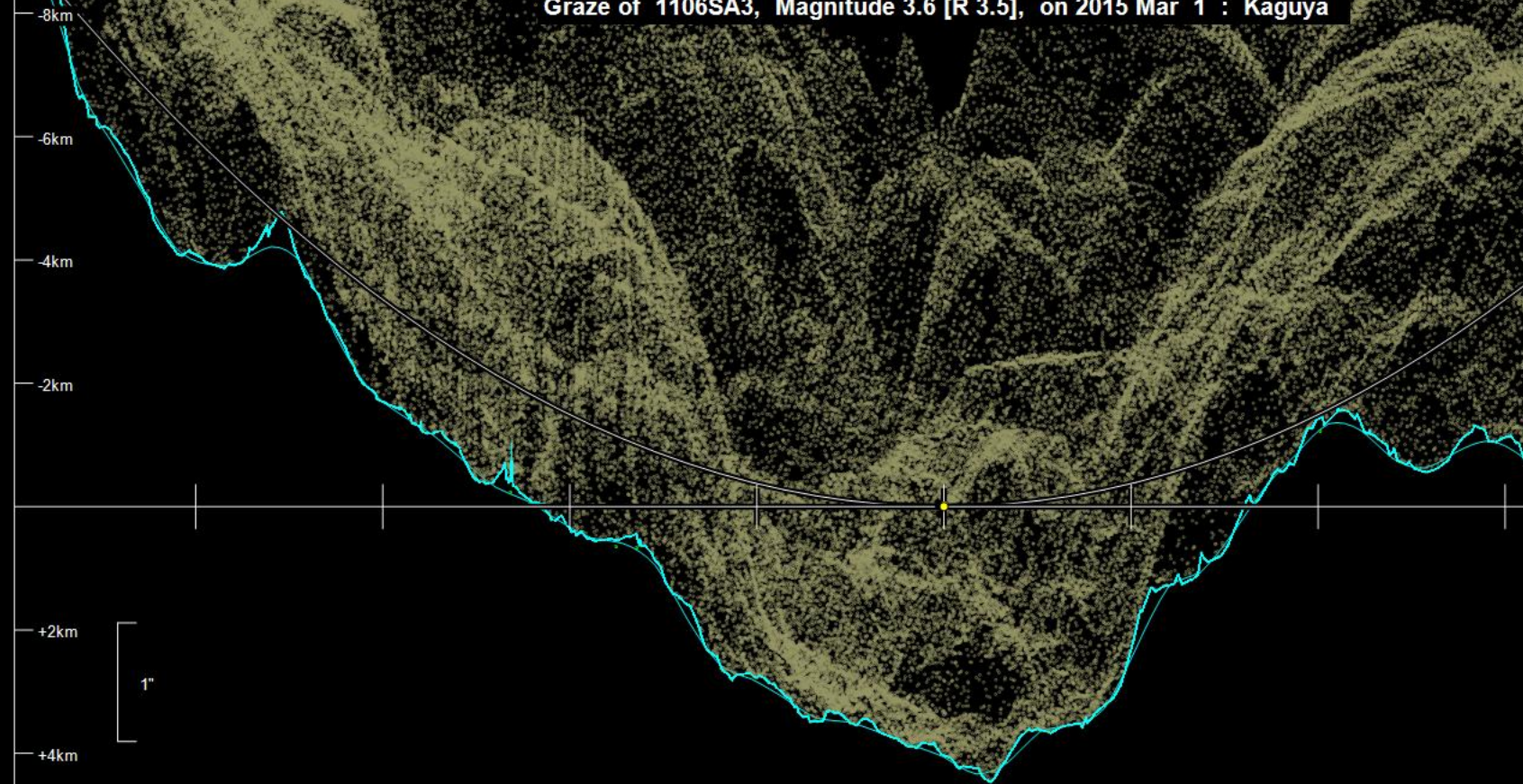


**For E. Long. -77.8**



-4m -3m -2m -1m +0m +1m +2m +3m

**Graze of 1106SA3, Magnitude 3.6 [R 3.5], on 2015 Mar 1 : Kaguya**



+2km  
1"  
+4km

1 Deg.

-4m -3m -2m -1m +0m +1m +2m +3m

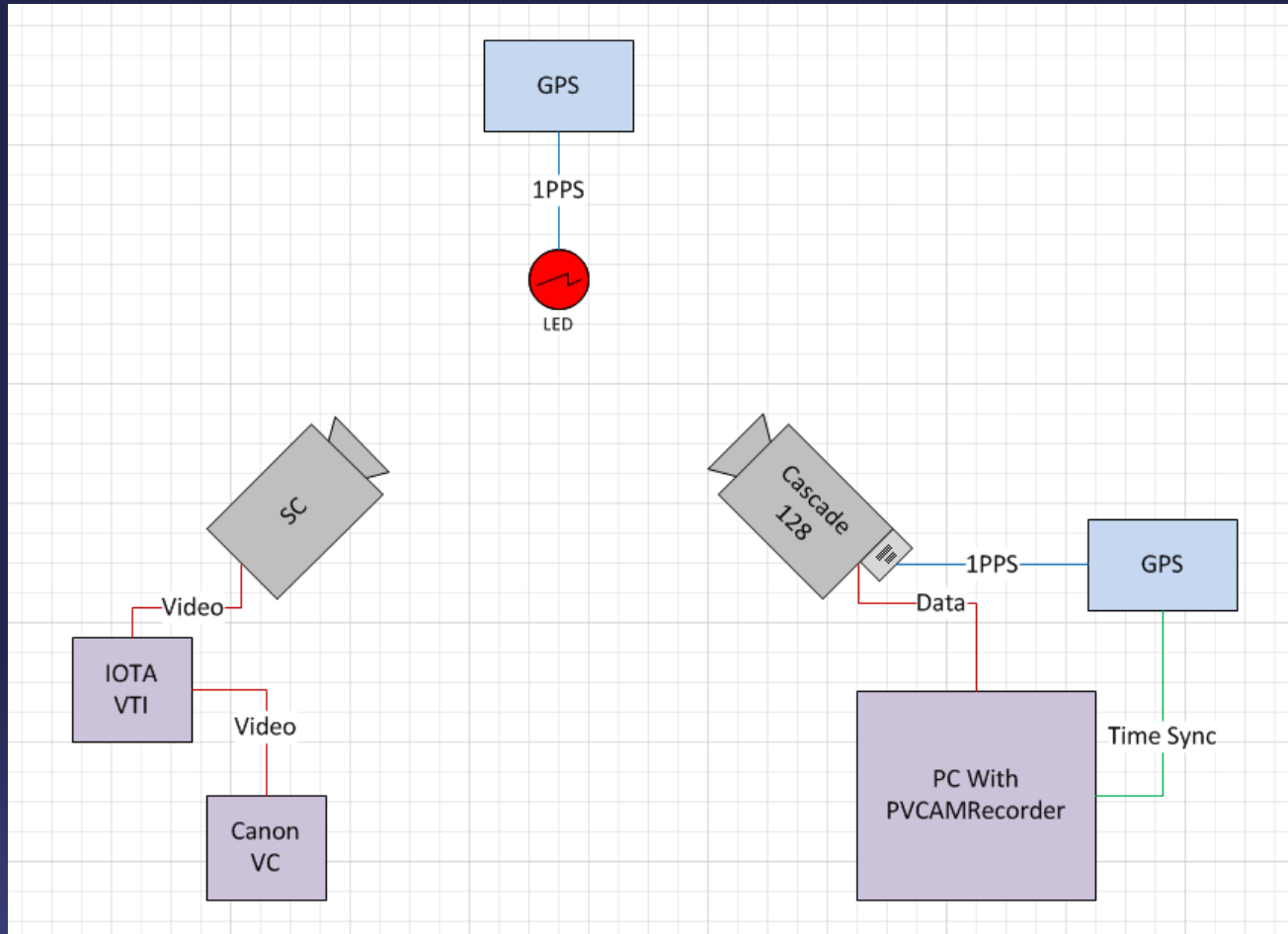
**For E. L<sup>+0m</sup>g. -77.8**

# Description

- The light curve shows ~13 transitions prior to the star completely disappearing, over a total time of about 0.3 seconds
  - Equates to about 200 meters on the moon
  - Most of these are between completely on to completely off, only about 3 partial signal levels
- It is exceedingly unlikely that the occultation geometry could support such an event, and the 200 Hz sampling would have to produce many more partial levels than we are seeing
  - The actual exposure time would have to be a small fraction of the 5 msec cadence to support this result, we believe the duty cycle is about 80%
- ***Our provisional conclusion is that this must be an instrumentally produced result***

# Diagnostic Testing (2014-2015)

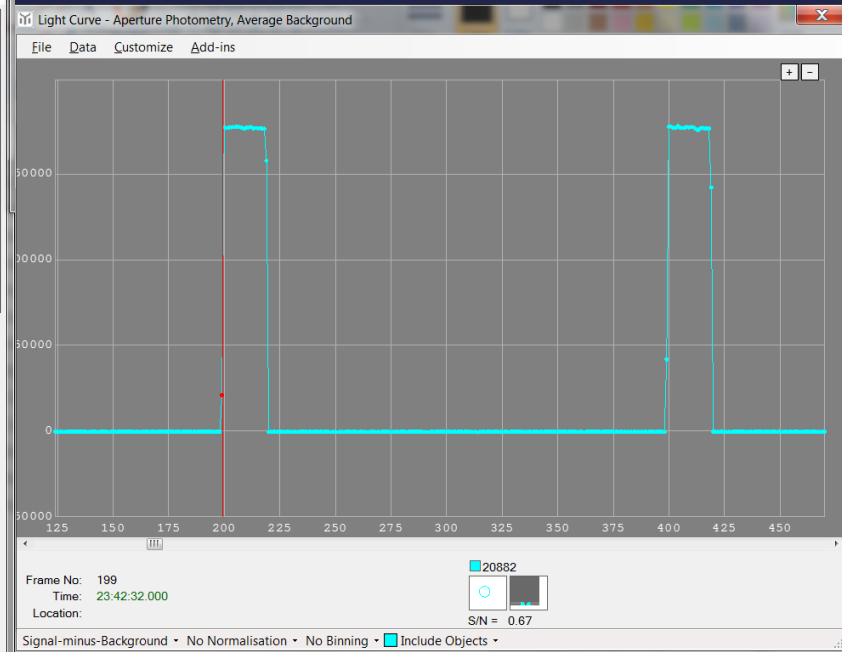
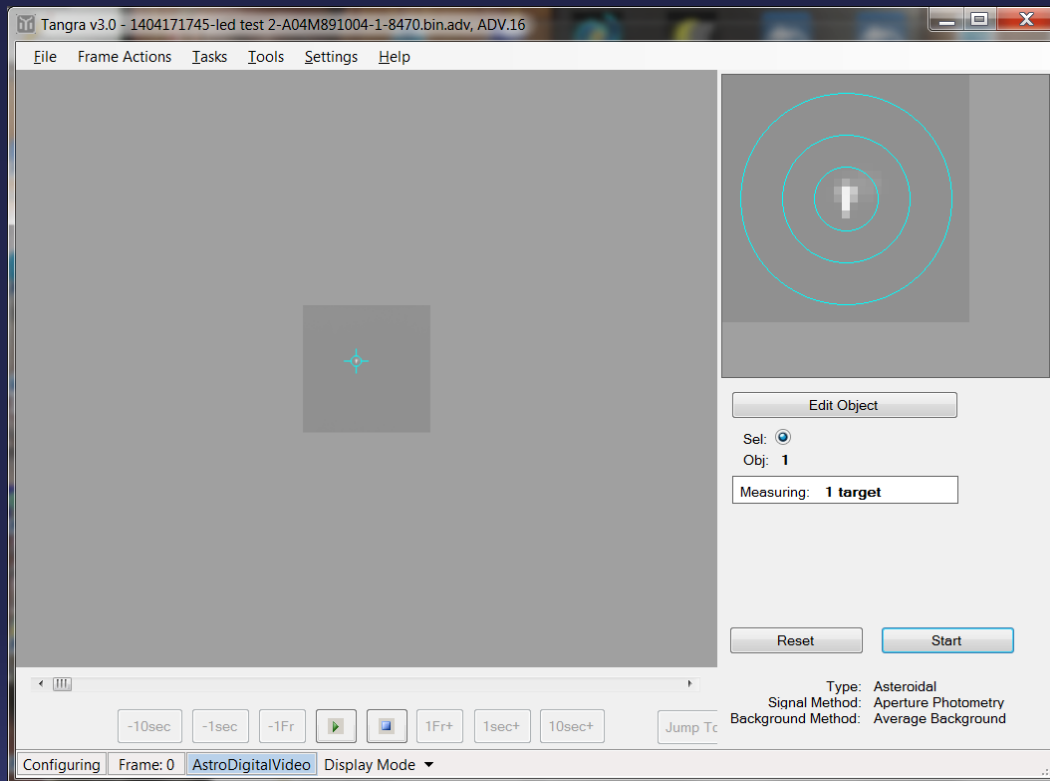
16



164CEX-2 & emCCD capturing LED blinking with 1pps GPS signal,



# Verification – New Capture Software <sup>17</sup>



Photometrics Cascade 128 emCCD capturing LED blinking with 1pps GPS signal at 200fps, Tangra light curve with timings also captured.

# New Equipment

- Two Innovation Foresight ONAG-XT's have been acquired, with adjustable focal reducers
  - These are designed for “On Axis Guiding”, and contain a dichroic beam splitter
    - Passes  $>780$  nm (induces slight astigmatism in this leg)
    - Reflects 350 to 750 nm
  - We have one here for you to look at, and we hope to use it on tonight's asteroid event



# New Equipment - ONAGs

- We intend to use these in two ways
  - To begin to look for wavelength dependence in the fast-frame rate data collected
  - To allow us to directly compare timing data collected with traditional RS-170 sensors to the emCCDs, without adding significant risk of data loss for high probability events

# New Equipment-AS212 Camera

- We have also acquired a ZW Optical ASI224MC camera for testing
  - This is in response to Russ Genet's request that we test one for Lunar Occultation work
  - These are very low noise color CMOS sensors, 1/3" format, USB 3.0 (0.75 to 1.5 e read noise)
  - Rolling shutter
  - Small and lightweight
  - Interestingly, they have very good sensitivity in the NIR, well matched to the ONAG transmitted path



# Access to Existing Hardware/Facilities

- Conard is observatory director for the new Roelke Observatory near Westminster, MD
  - This has a 14" SCT on a heavier mount than Conard's own Willow Oak Observatory, and should allow heavier payloads
- Conard likely will soon have access to a 0.6 m R-C at his place of employment
- We are trying to obtain access to a 0.8 m R-C at a Baltimore area university as well
- All these potential assets should allow us to test these heavy cameras on relatively larger apertures
  - Continue to look to try faint TNO events

# Plans for the Next Year

- Begin regularly performing dual camera measurements on both lunar and asteroid events
  - Some of these will include the ZWO camera
- Use high speed cameras to look for diffraction phenomena
- Use the emCCDs on larger university-based for very faint events
  - Actual TNO events or very faint asteroid events

# Contact information

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  - [Bruce Holenstein: bholenstein@gravic.com](mailto:bholenstein@gravic.com)