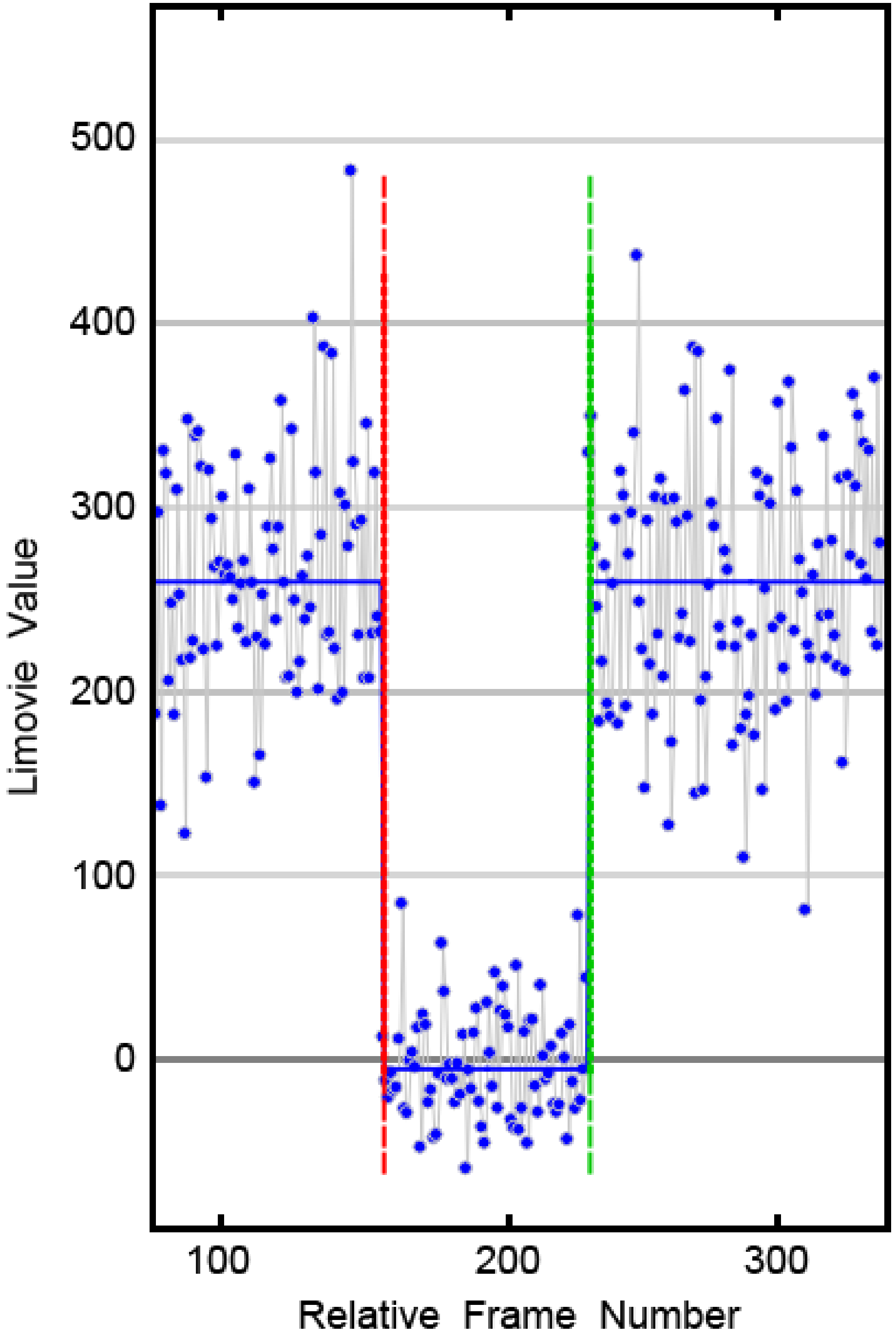
The appearance of light curves of near-Earth asteroid events

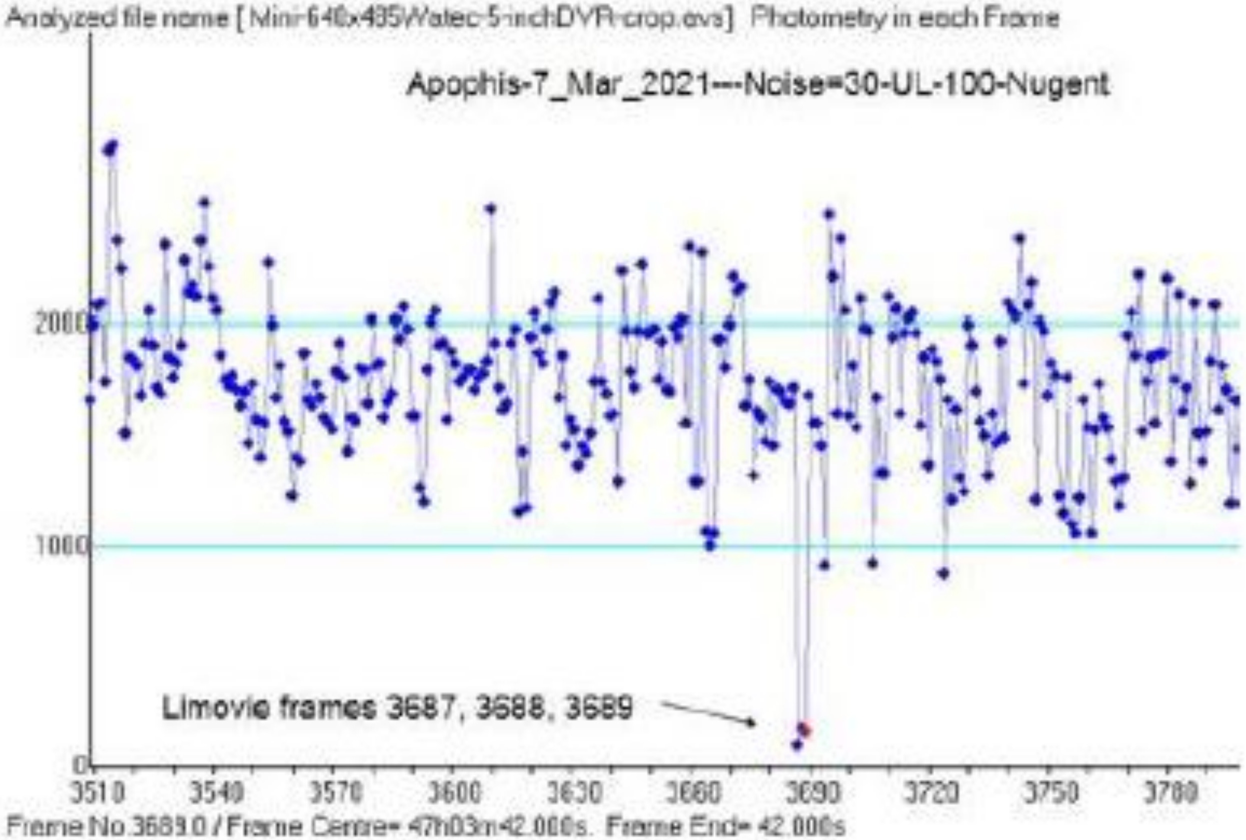
Roger Venable
IOTA meeting, August 14, 2022



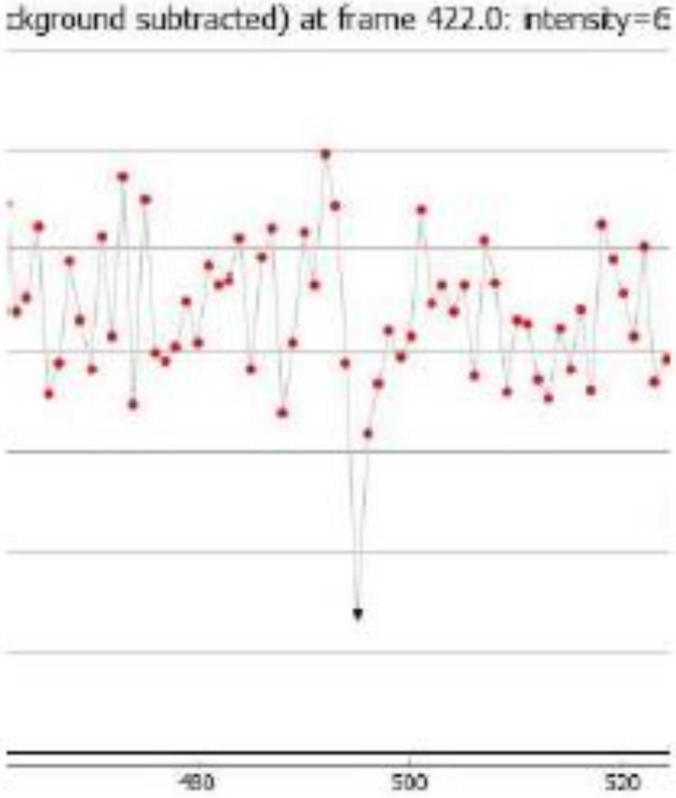
This is typical of occultation light curves involving faint main belt asteroids: the brightness abruptly drops to zero although there may be a single frame of intermediate brightness; there is a flat bottom; and there are no evident diffraction spikes before or after the occultation, nor is there a diffraction spike in the middle of the nadir of the event.

Light curve of (1984) Fedynskij occulting a star of magnitude 11.3 on 2021-12-24, recorded by Roger Venable using an SCT of 230 mm aperture and a Watec 910HX camera at 30 frames per second.

Dunhams



Nugent

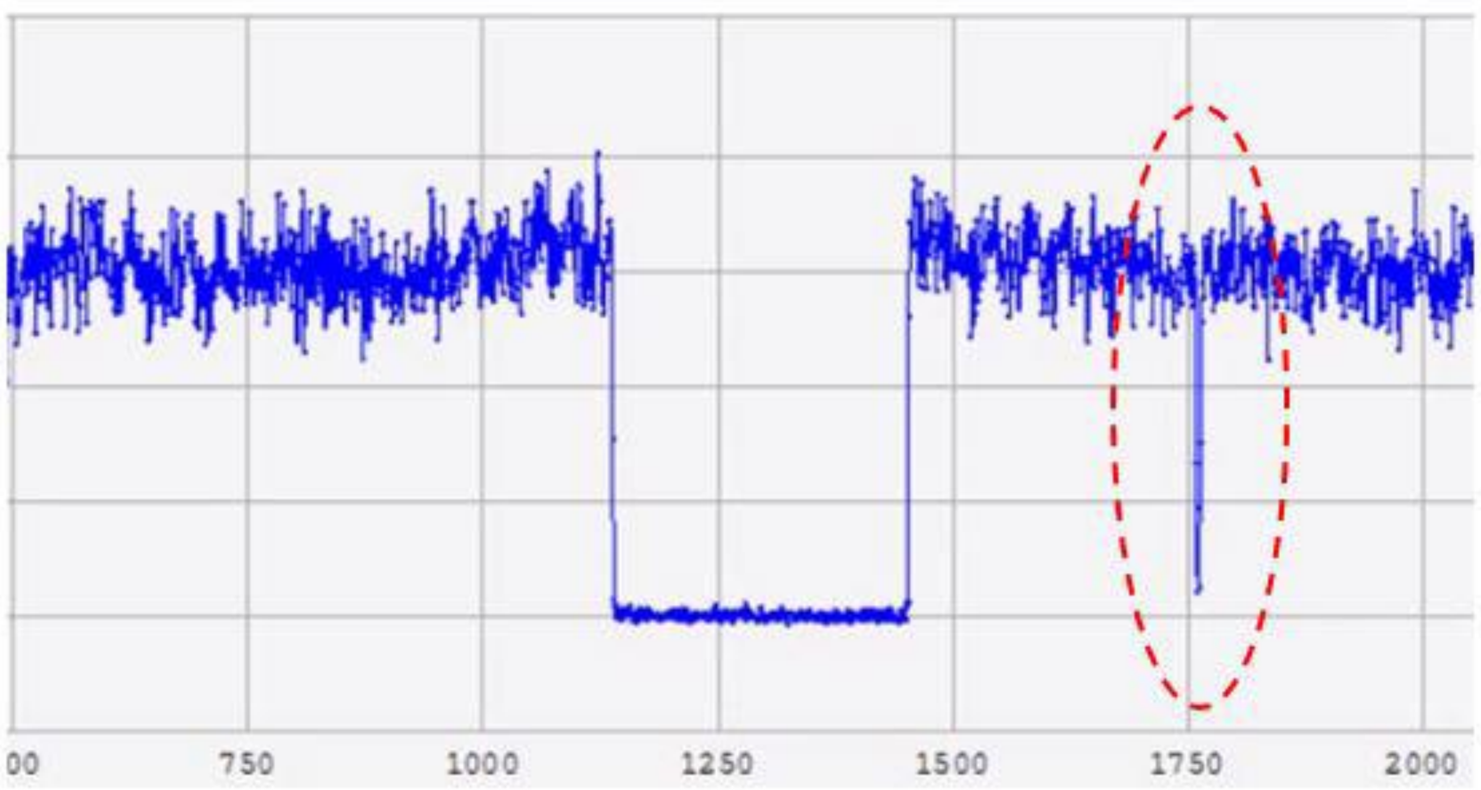


Dunhams

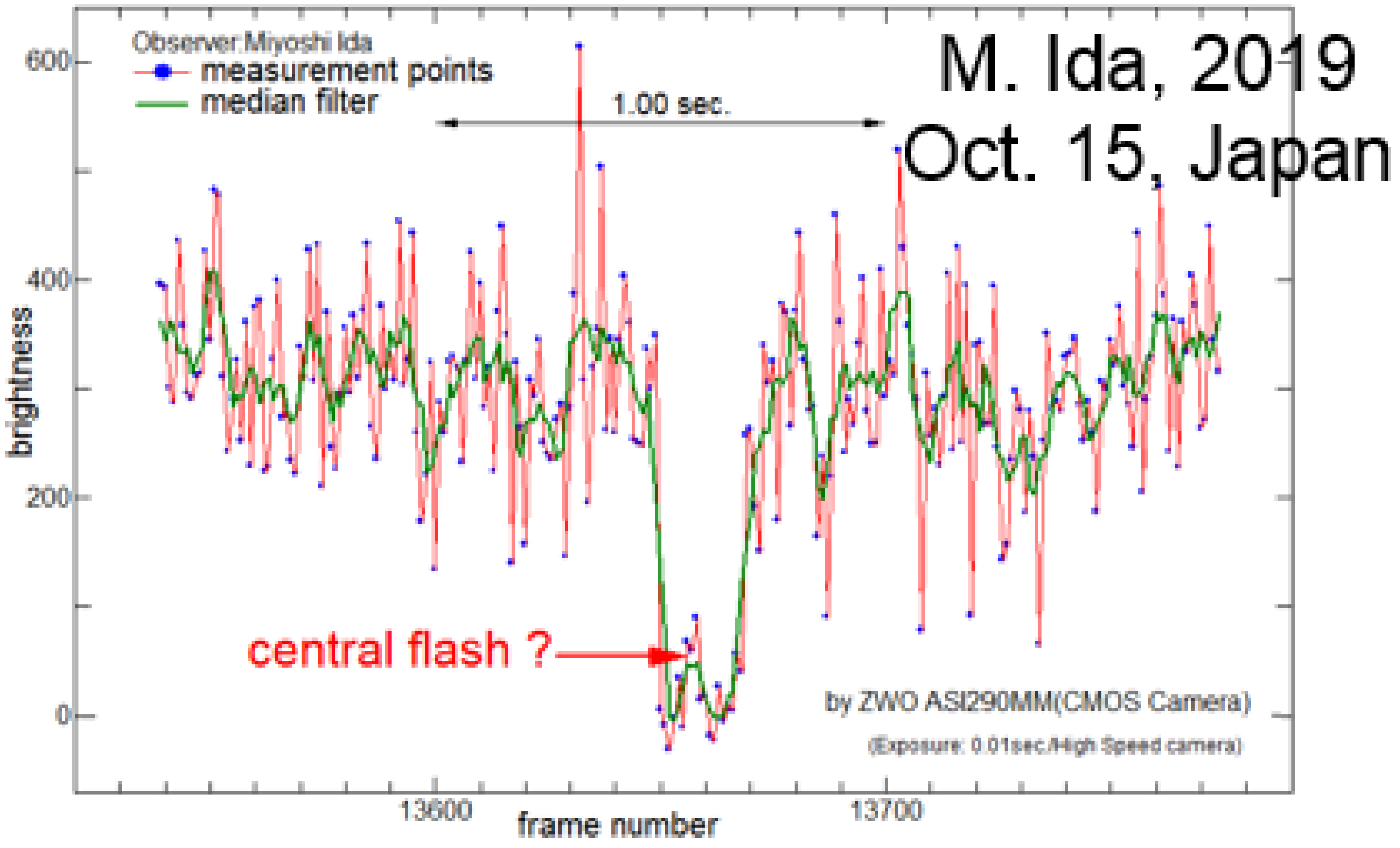
The three positive chords in the first Apophis occultation, at Oakdale , Louisiana. The occultations were very brief, a common feature of occultations by NEA's. This brevity makes instrument selection and settings critical regarding the interaction among frame rate, aperture, and event duration.

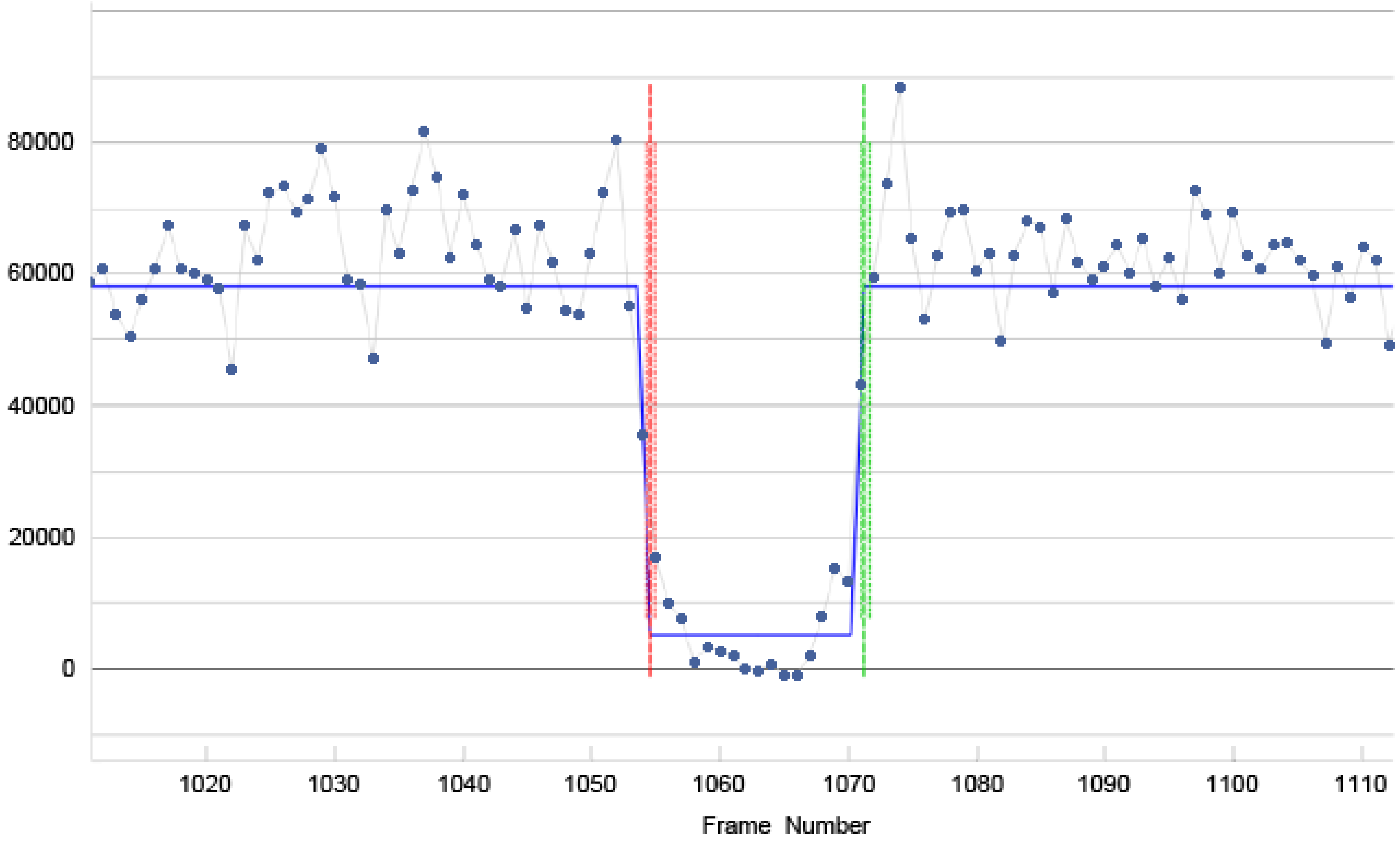
Discovery of Satellites of Asteroids

Trojan Asteroid (911) Agamemnon,
observed by Steve Conard, Gamber, MD



2012 January 19: occultation of HIP 41337


M. Ida, 2019
Oct. 15, Japan
Observer:Miyoshi Ida
measurement points
median filter
1.00 sec.
600
400
200
0
brightness
central flash ?
by ZWO ASI290MM(CMOS Camera)
(Exposure: 0.01sec./High Speed camera)
13600
13700
frame number



Kai Getrost's light curve of the occultation of a star of magnitude 10.1 by 99942 Apophis on 2021-04-11, using a Dobsonian telescope of 400 mm aperture and a QHY174M GPS camera at 100 frames per second.

Four strange phenomena with very small asteroids:

1. Incomplete disappearance of the star.

2. Brightness spikes immediately before and after the event, and also during the middle of the event.

3. Rounded event bottom.

4. Multiple frames of intermediate brightness.

Three causes of these phenomena:

1. Fresnel diffraction effects

2. Frame rate effects

3. Effects of the subtended diameter of the star

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The "Fresnel length" has been defined in several ways in the astronomical literature, but for the purpose of this presentation we'll calculate it as:

Fresnel length = sqrt(lambda*distance/2)

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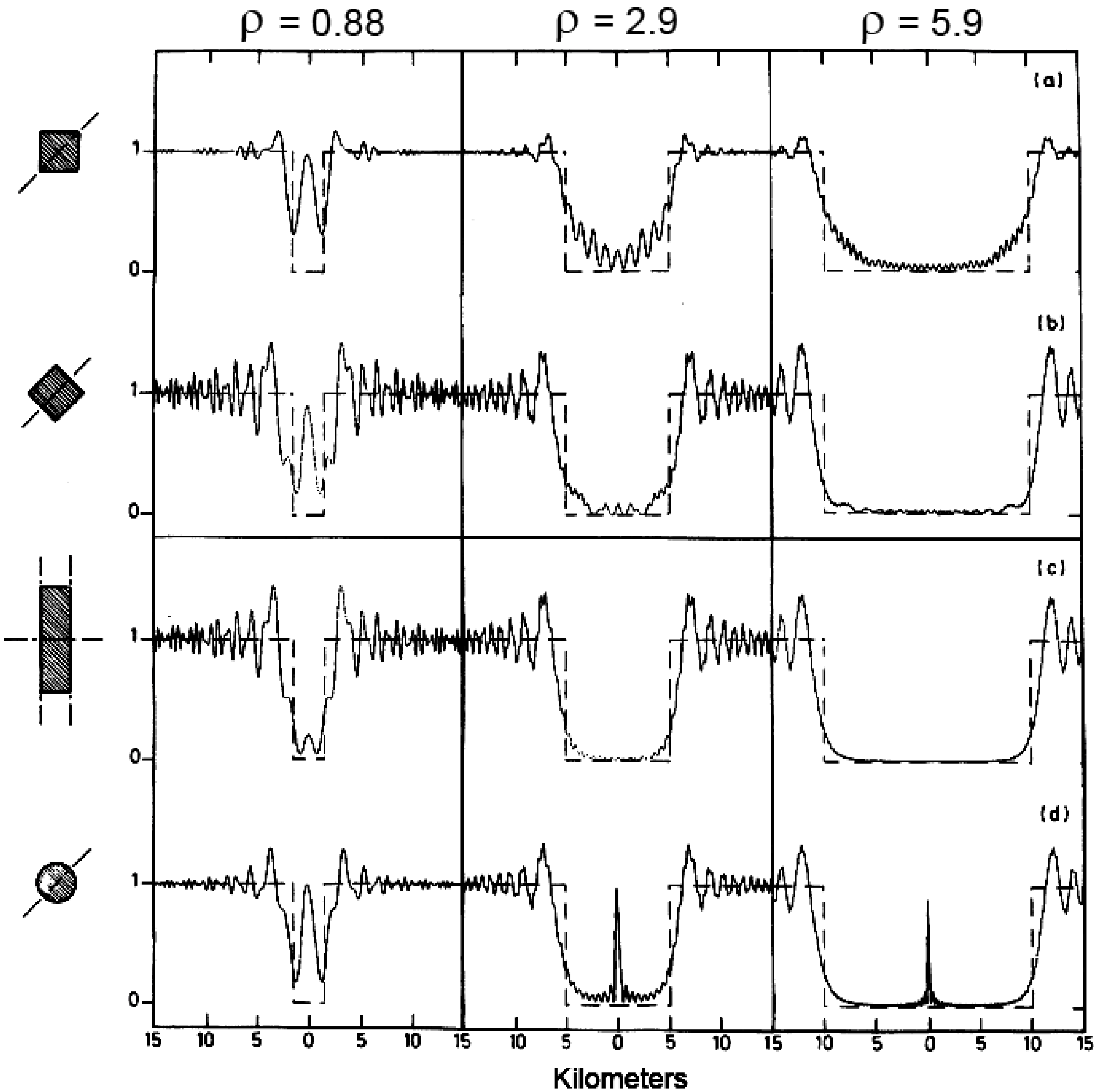
A convenient way to represent this is to divide the asteroid's radius by the Fresnel length. The resultant value is often called "rho" and is represented by the Greek letter itself: ρ. So, a value of ρ of about 1 is associated with very prominent diffraction effects.



Roques, Moncuquet, & Sicardy (1987). "Stellar occultations by smal bodies." AJ 93(6): 1549-1558.

Previous observations of occultations and appulses by 99942 Apophis

UT Date	*Star*	*Star Vis. Mag.*	*Star Diam* (mas)*	*Apophis Dist. (AU)*	*Apophis Sky Motion (mas/sec)*	*F.L.** (m)*	*ρ*[×]	*Max. Duration*[××] *(sec)*
2021 March 7	HIP 45887	8.58	0.176	0.11273	56	71	2.4	0.075
2021 March 22	TYC 0218-00224-1	10.1	0.0709	0.12386	38	75	2.3	0.10
2021 April 4	TYC 0789-01041-1	11.4	0.0671	0.14089	23	80	2.1	0.14
2021 April 10	UCAC4 528-046251	12.6	0.0167	0.14889	19	82	2.1	0.17
2021 April 11	TYC 1376-00848-1	10.1	0.0557	0.14983	19	82	2.1	0.16
2021 May 6	TYC 1929-01244-1	11.6	0.0231	0.16851	15	87	2.0	0.18
2021 Sept 27	TYC 1392-01042-1	8.7	0.0225	0.87972	35	199	0.85	0.015
2022 April 9	TYC 5782-01139-1	8.5	0.379	0.53721	58	155	1.1	0.015

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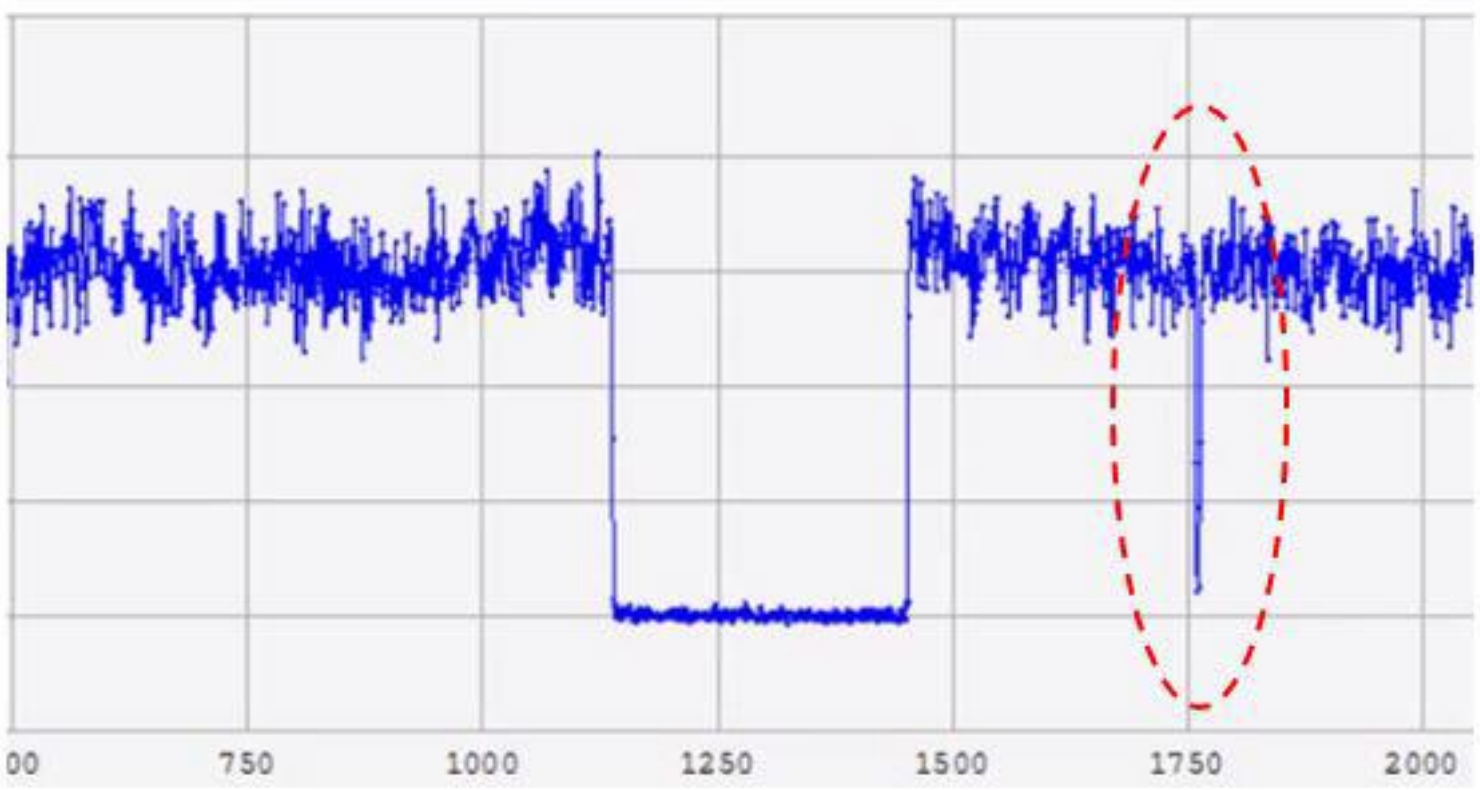

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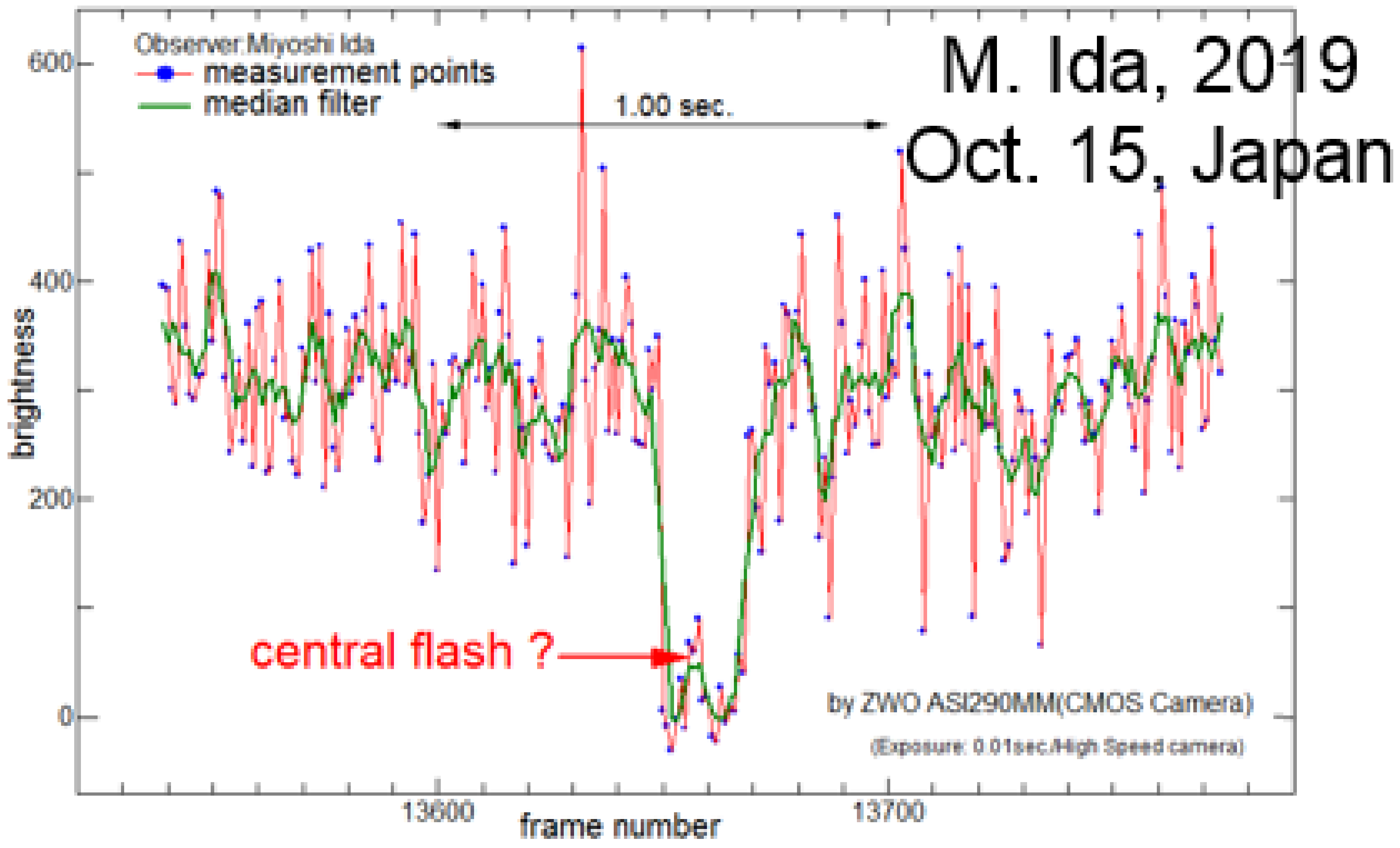
Observer:Miyoshi Ida
measurement points
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1.00 sec.
M. Ida, 2019
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600
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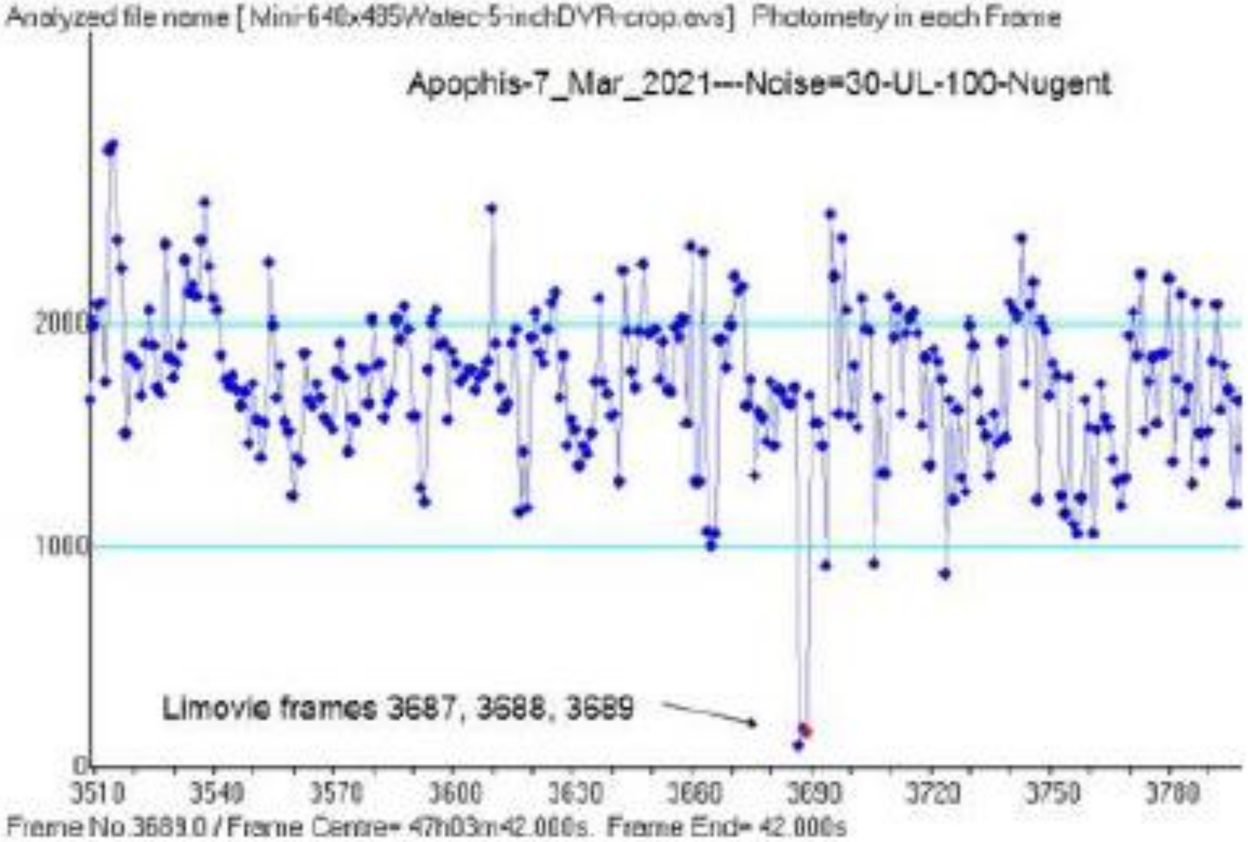

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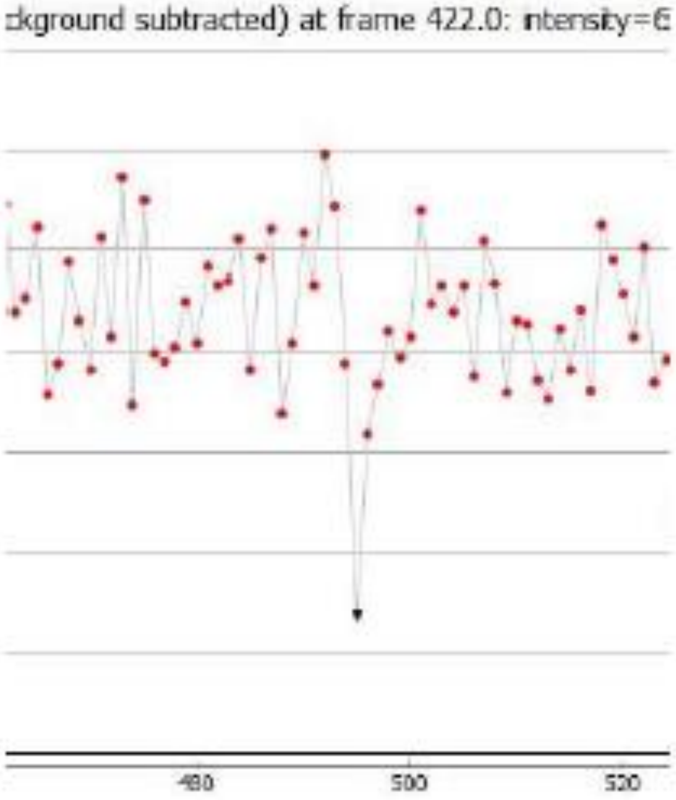

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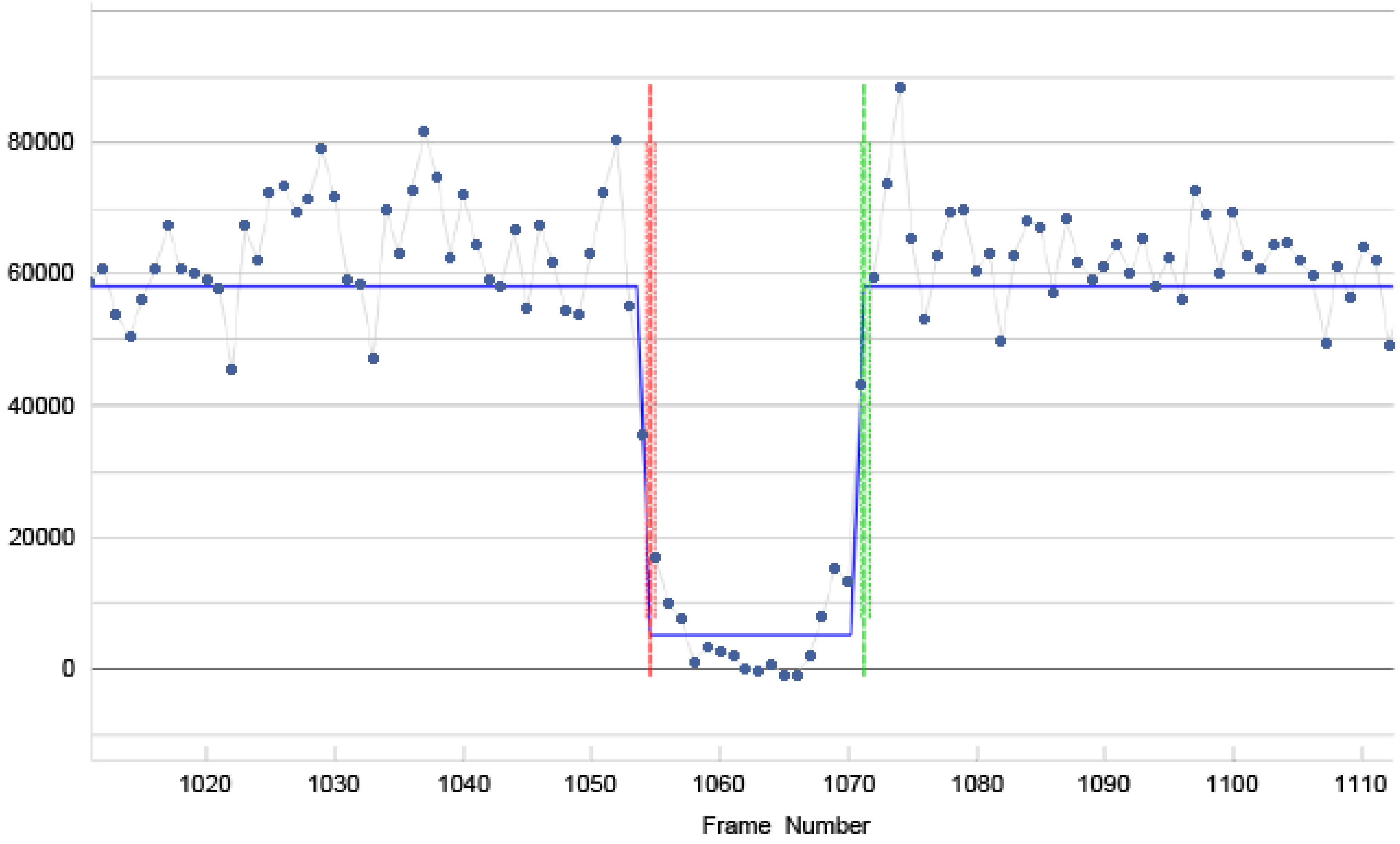

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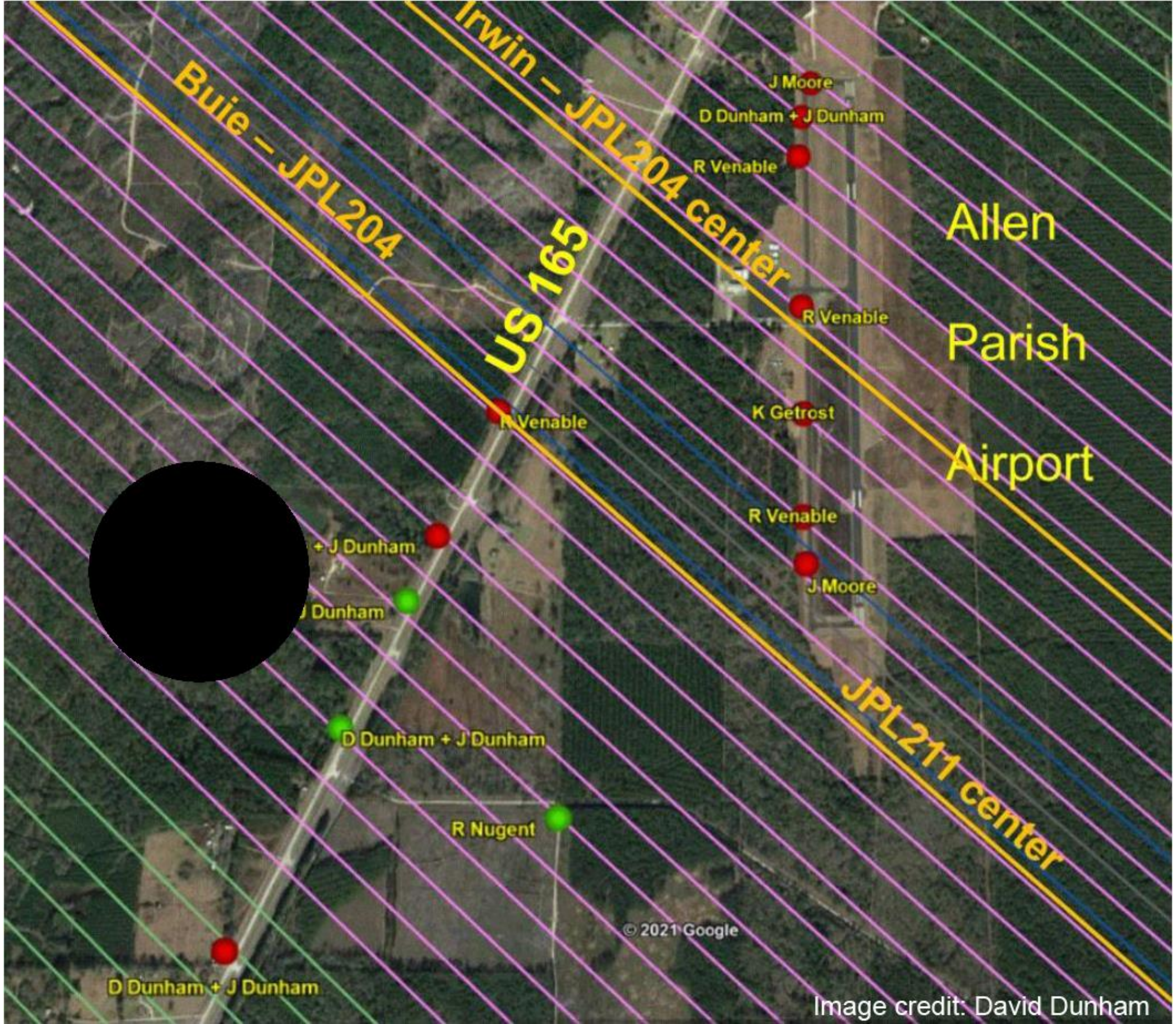
Irwin – JPL204 center
Buie – JPL204
US 165
J Moore
D Dunham + J Dunham
R Venable
Allen
Parish
Airport
R Venable
R Venable
K Getrost
R Venable
J Moore
[redacted] + J Dunham
[redacted] J Dunham
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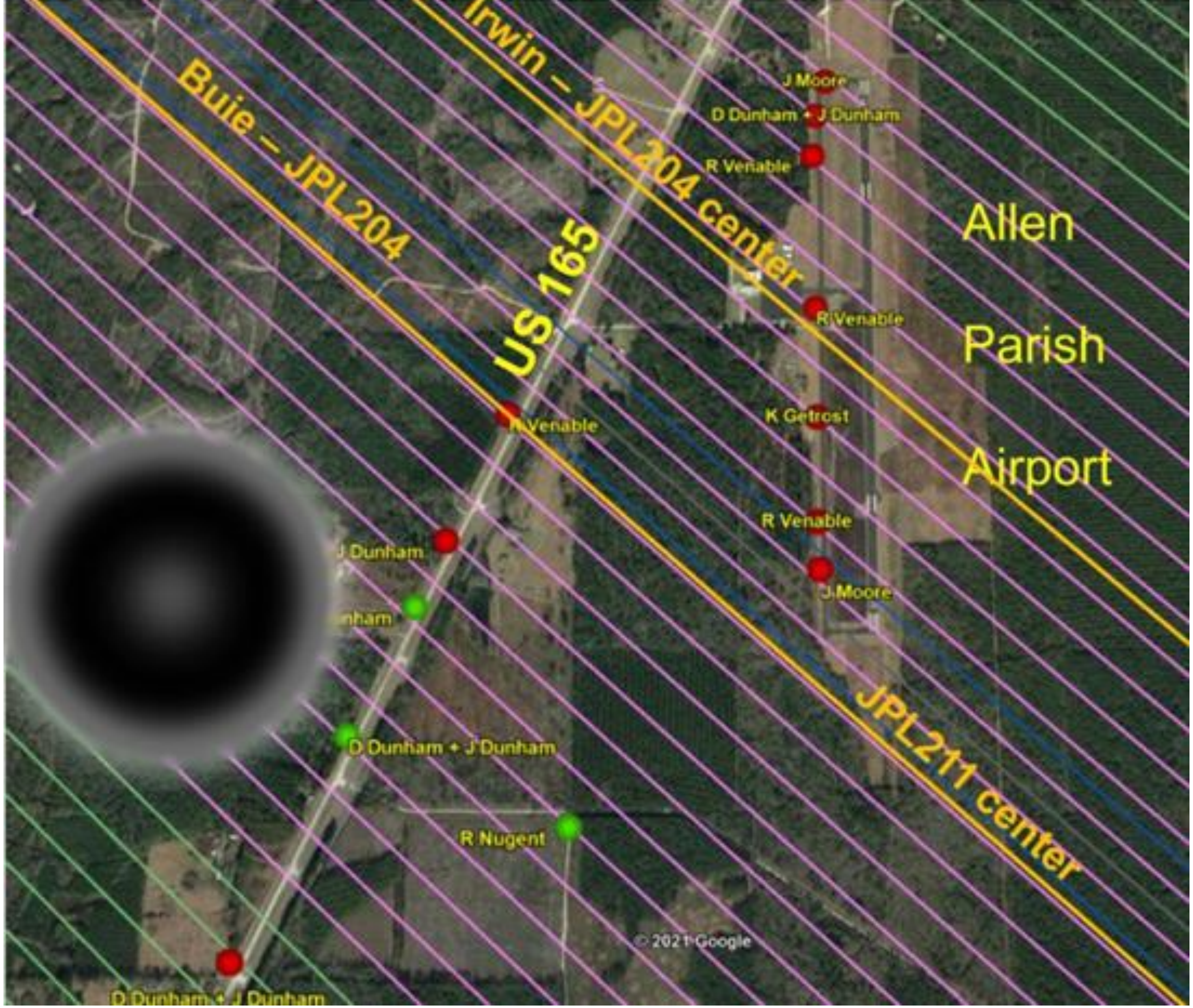
R Nugent
JPL211 center
© 2021 Google
D Dunham + J Dunham
Image credit: David Dunham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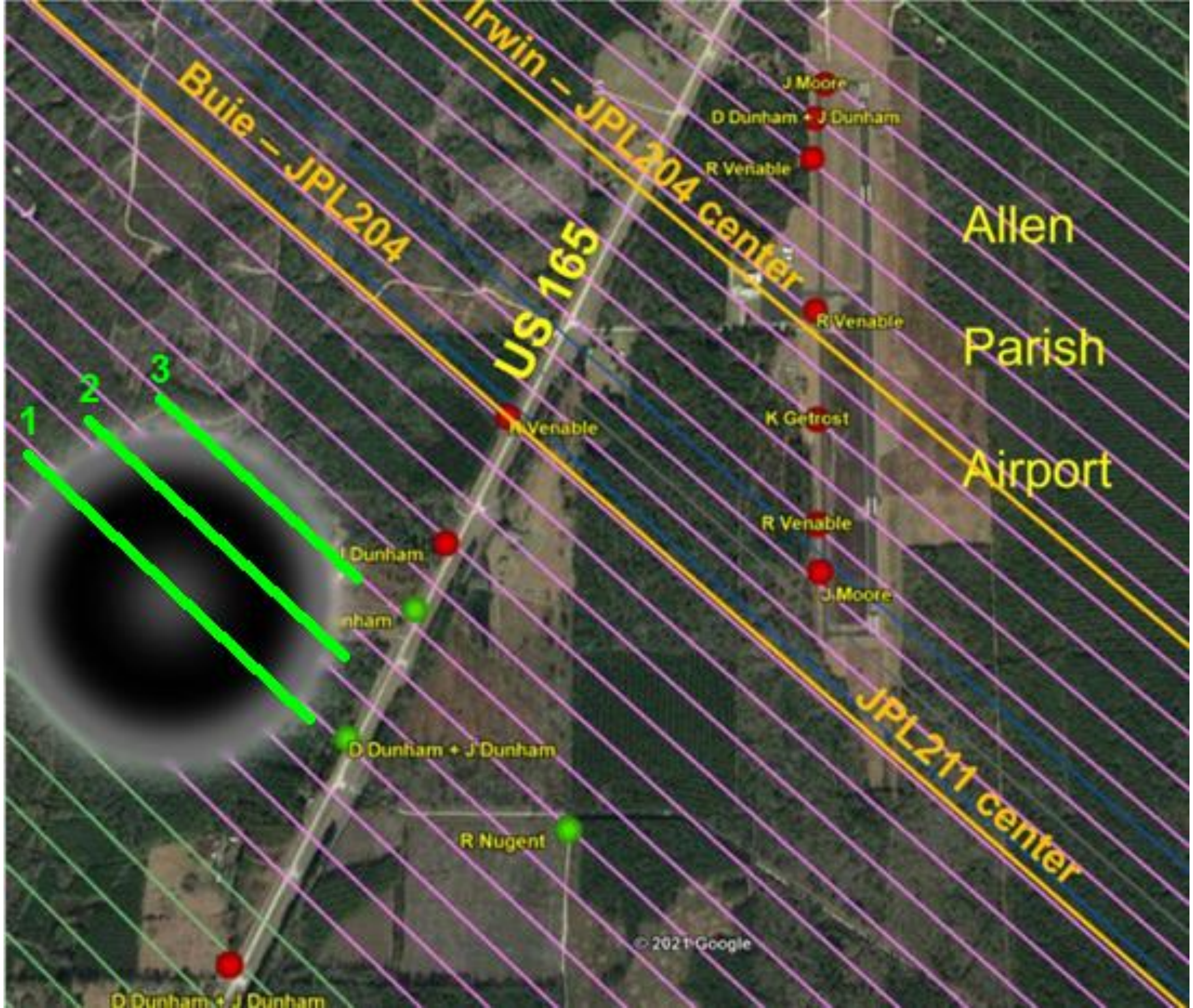
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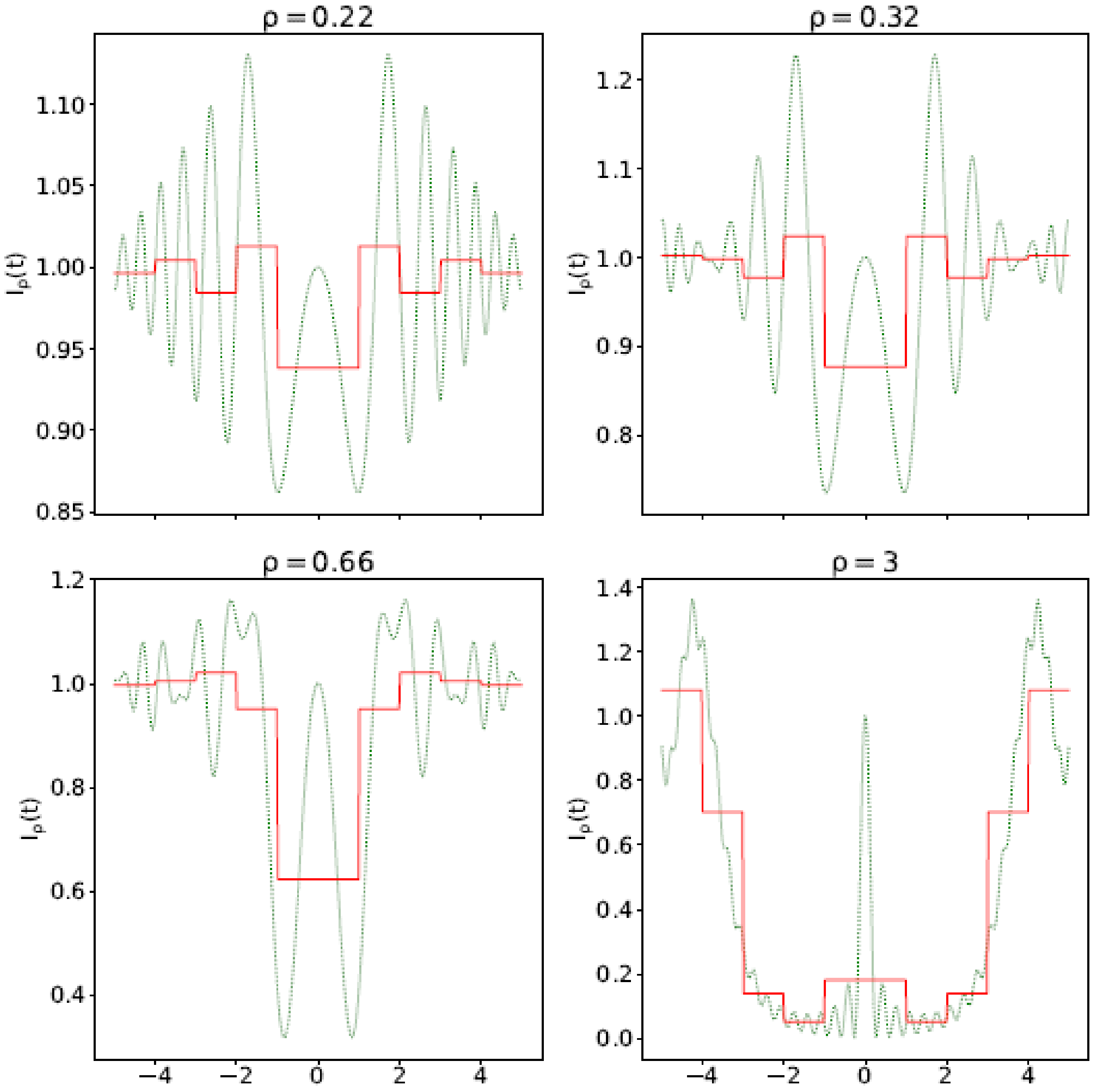

Figure 1. Occultation lightcurves for the values of ρ_{min} (ratio of ISO radius to the Fresnel scale) in Table 1 (dotted green lines), and sampled lightcurves at temporal resolution, t_F (solid red lines). For a transverse speed $v_\perp$ at a distance D_L, the time unit, $t_F = 0.1\mathrm{s}\,(D_L/20\ \mathrm{AU})^{1/2}(v_\perp/10\ \mathrm{km\ s^{-1}})^{-1}$.

Siraj A, and Loeb A (2020). "Detecting interstellar objects through stellar occultations." arXiv:2001.02681v2 [astro-ph.EP] 11 Feb 2020.

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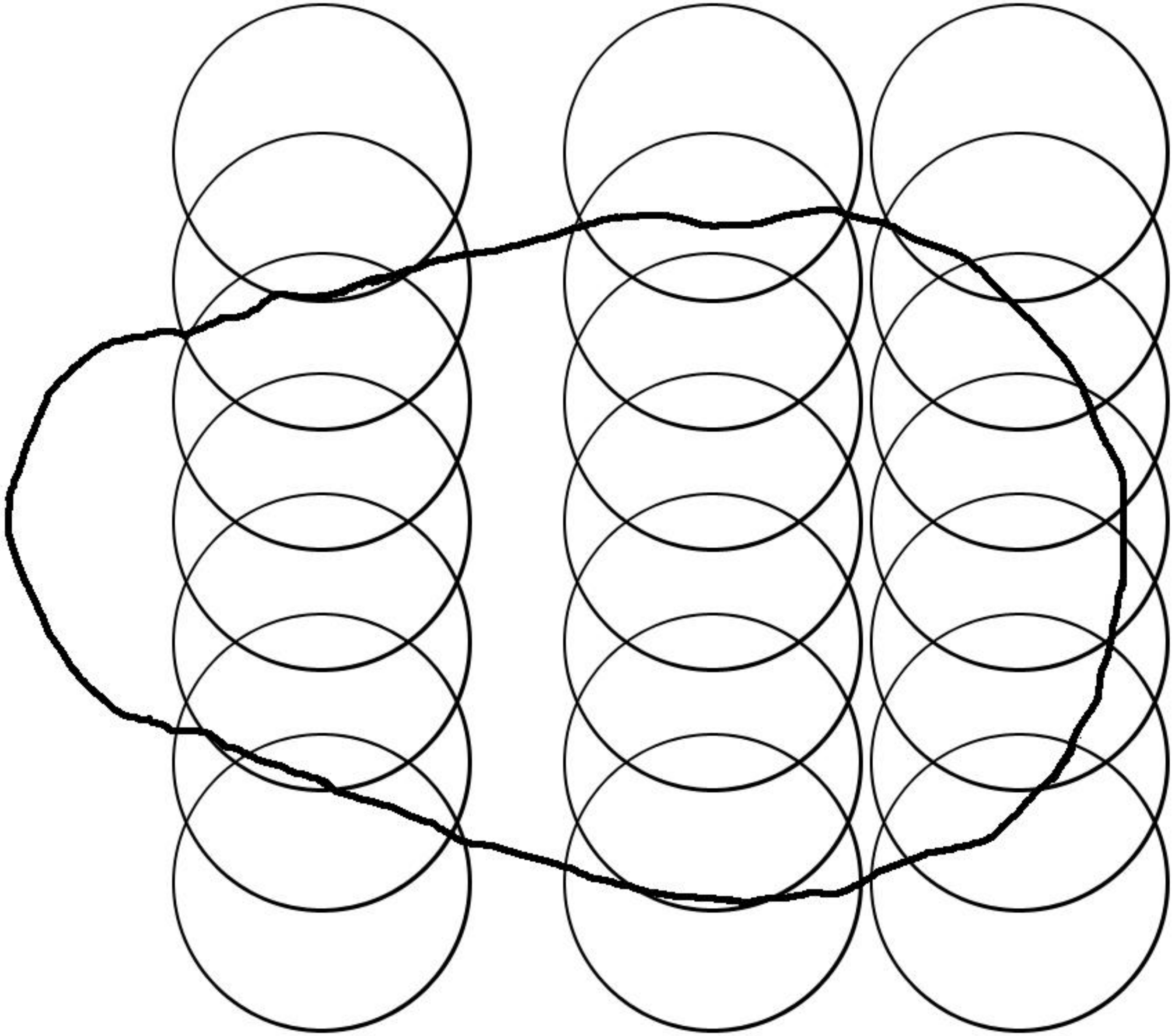
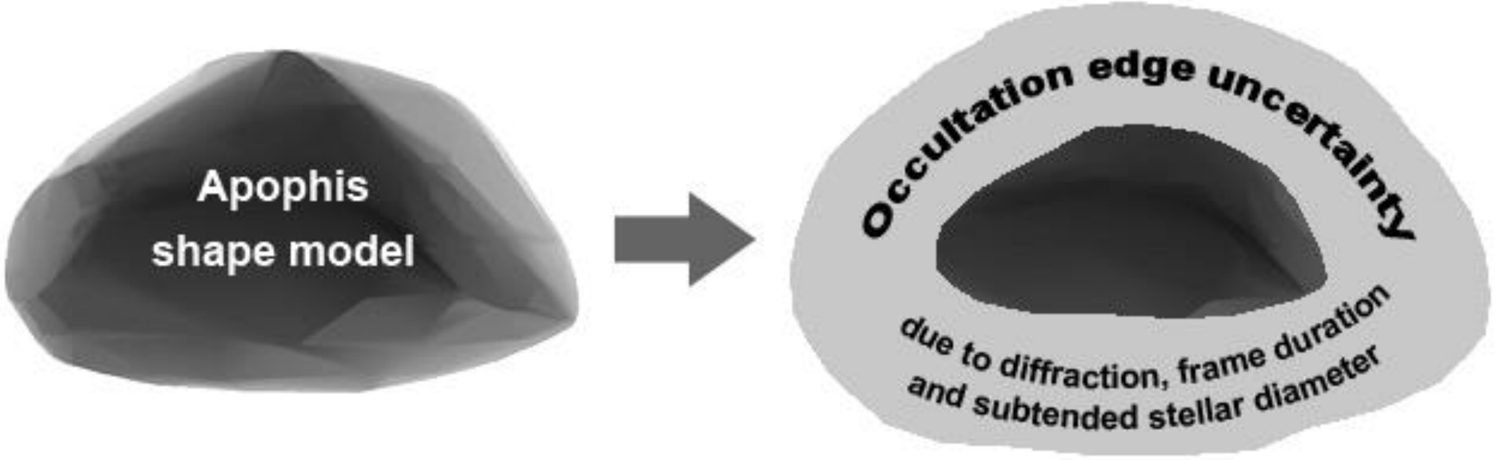
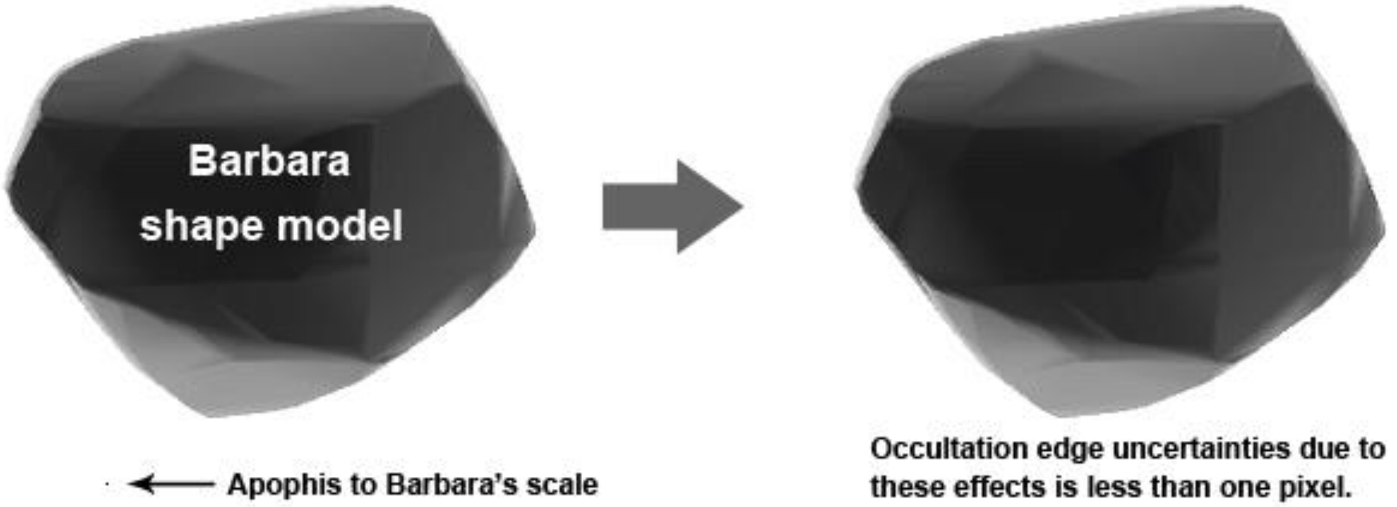




These uncertainties are large compared to the small size of Apophis. . .



. . . but have no effect on 45 km Barbara, a MB asteroid.

Transneptunian objects

	Diameter	*Distance*	*Wavelength*	*Fresnel*	
Object	*(km)*	*(km)*	*(nm)*	*length*	*Rho*
Pluto	2377	5.04E^9	600	38.9	30.6
Charon	1212	5.04E^9	600	38.9	15.6
Styx	11	5.04E^9	600	38.9	0.1
Nix	38	5.04E^9	600	38.9	0.5
Kerberos	13	5.04E^9	600	38.9	0.2
Hydra	39	5.04E^9	600	38.9	0.5
Quaoar	1110	6.54E^9	600	44.3	12.5
Weywot	170	6.54E^9	600	44.3	1.9
Haumea	1600	6.45E^9	600	44.0	18.2
Hi'kaka	310	6.45E^9	600	44.0	3.5
Namaka	170	6.45E^9	600	44.0	1.9

Discussion?

Questions?

Answers?