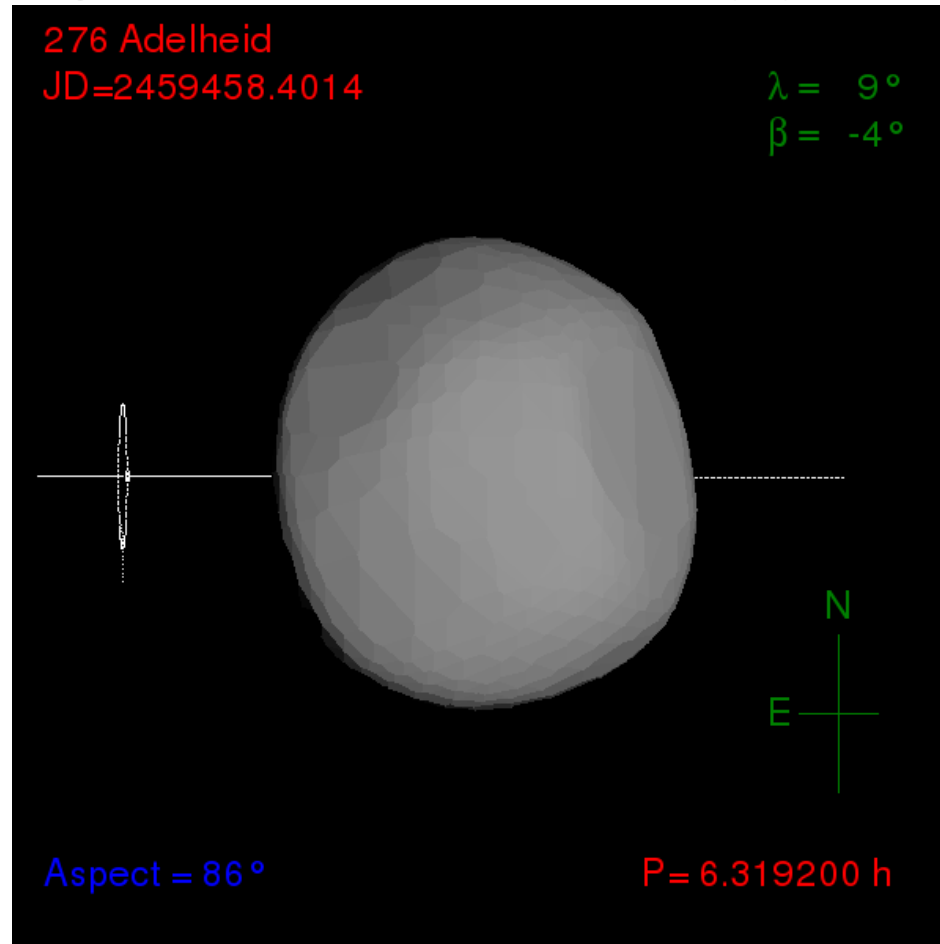


(276) Adelheid: Evidence for Satellite & Upcoming Confirmation Opportunities



Kevin D. Green
University of New Haven
Westport Astronomical Society

Public Telescopes in Westport, CT



Westport Astronomical Society

Westport Astronomical Society is a local institution dedicated to the promotion of all things Astronomical

The screenshot shows a web browser window with the URL <https://www.was-ct.org>. The website features a dark theme with a circular logo on the left containing the letters 'WAS' and 'WESTPORT ASTRONOMICAL SOCIETY'. A horizontal navigation menu includes links for 'Calendar', 'Membership', 'KB1WLW', 'Gallery', 'About Us', and 'Resources'. Below the menu, a large banner image of a starry night sky with a red nebula is displayed. Overlaid on the banner is a text box that reads 'Weekly Star Parties!' and another box below it that says 'Join us every clear Wednesday night from 8-10 pm'. The Windows taskbar at the bottom shows the date and time as 7:33 PM on 3/14/2018.

Recent Observatory Donation

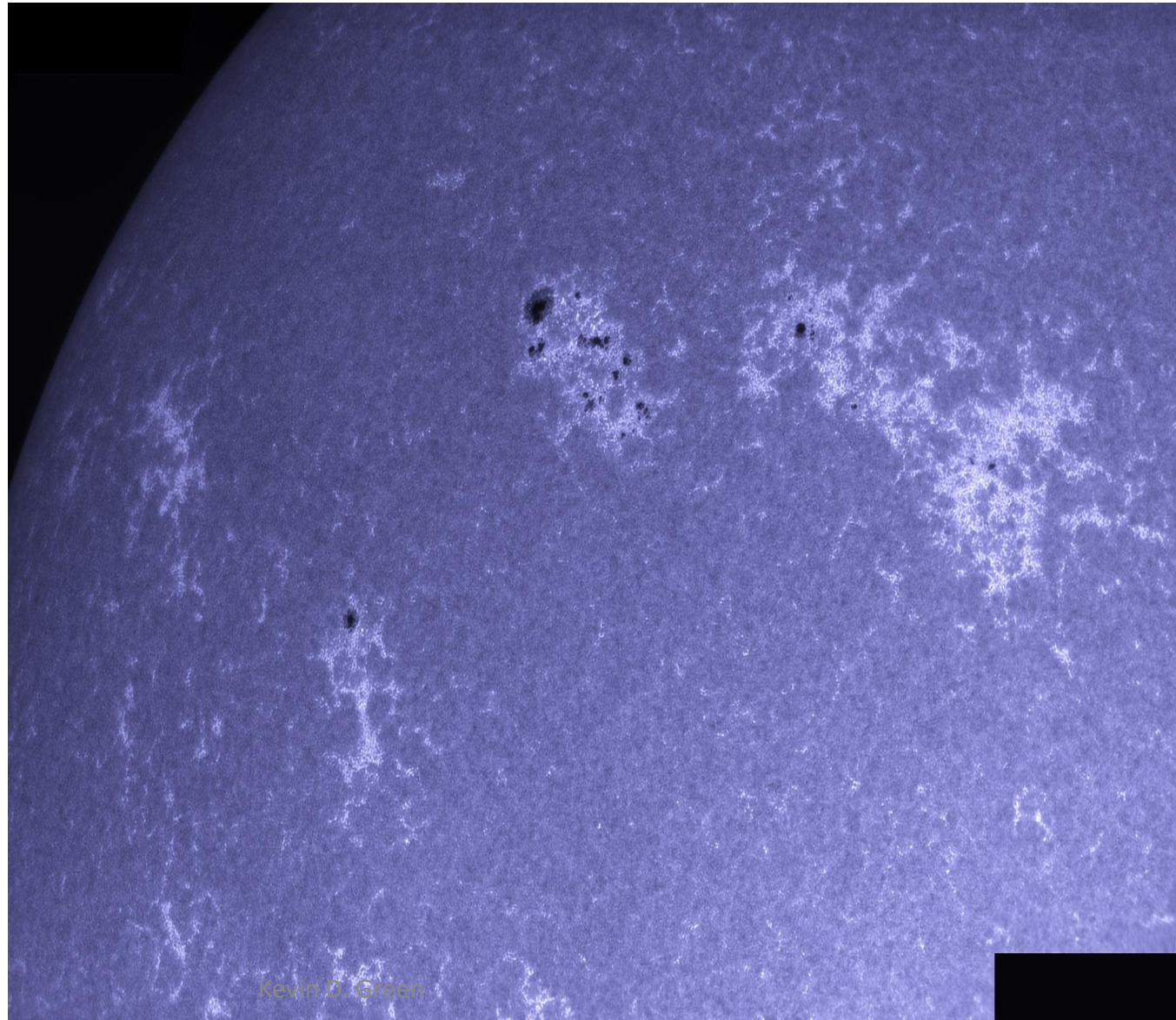


Courtesy of Ted Schimenti of Greenwich.

WAS Activities

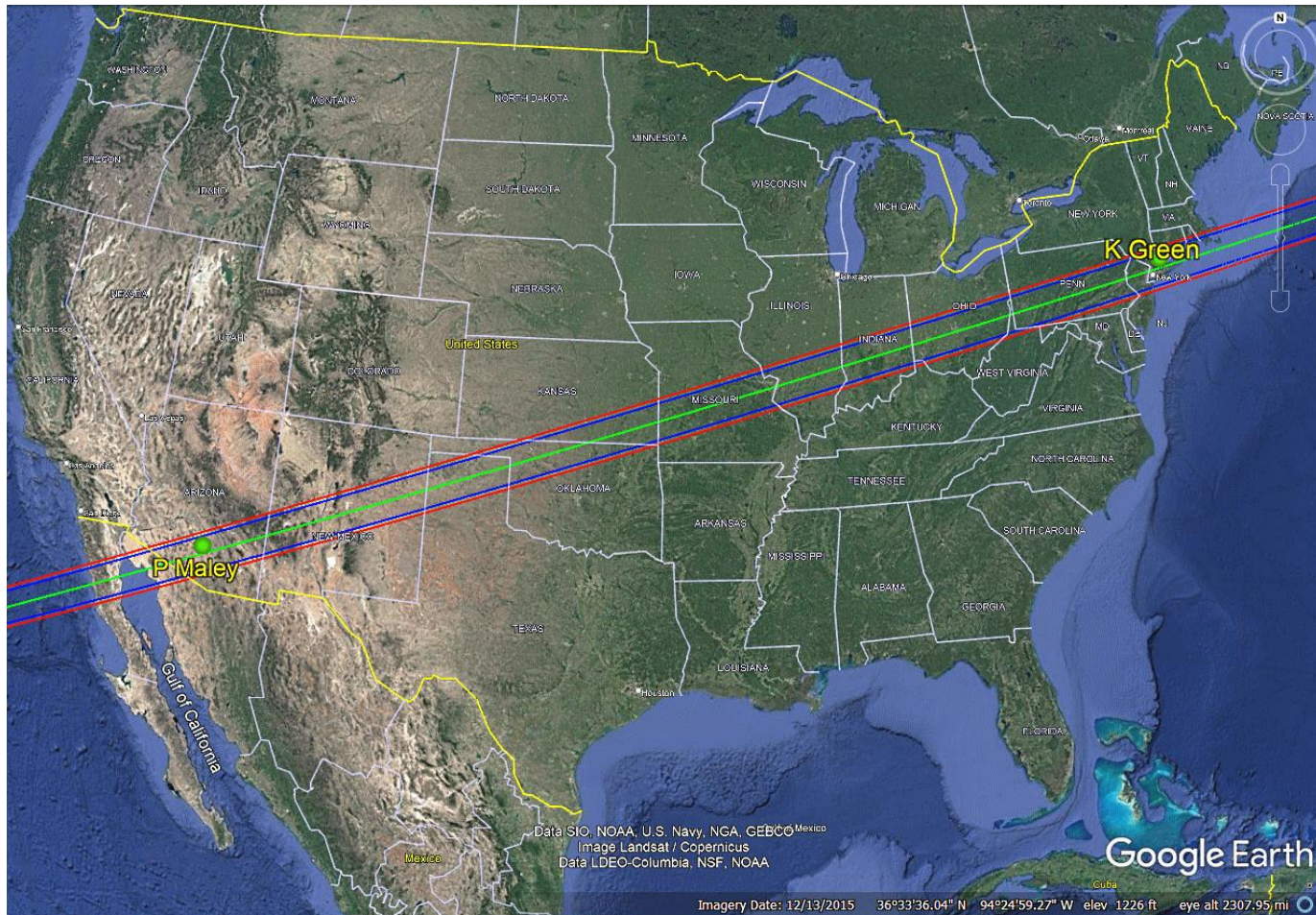
Astrophotography
is a popular activity
at WAS.

Solar image (Calcium)
taken by Franco Fella.

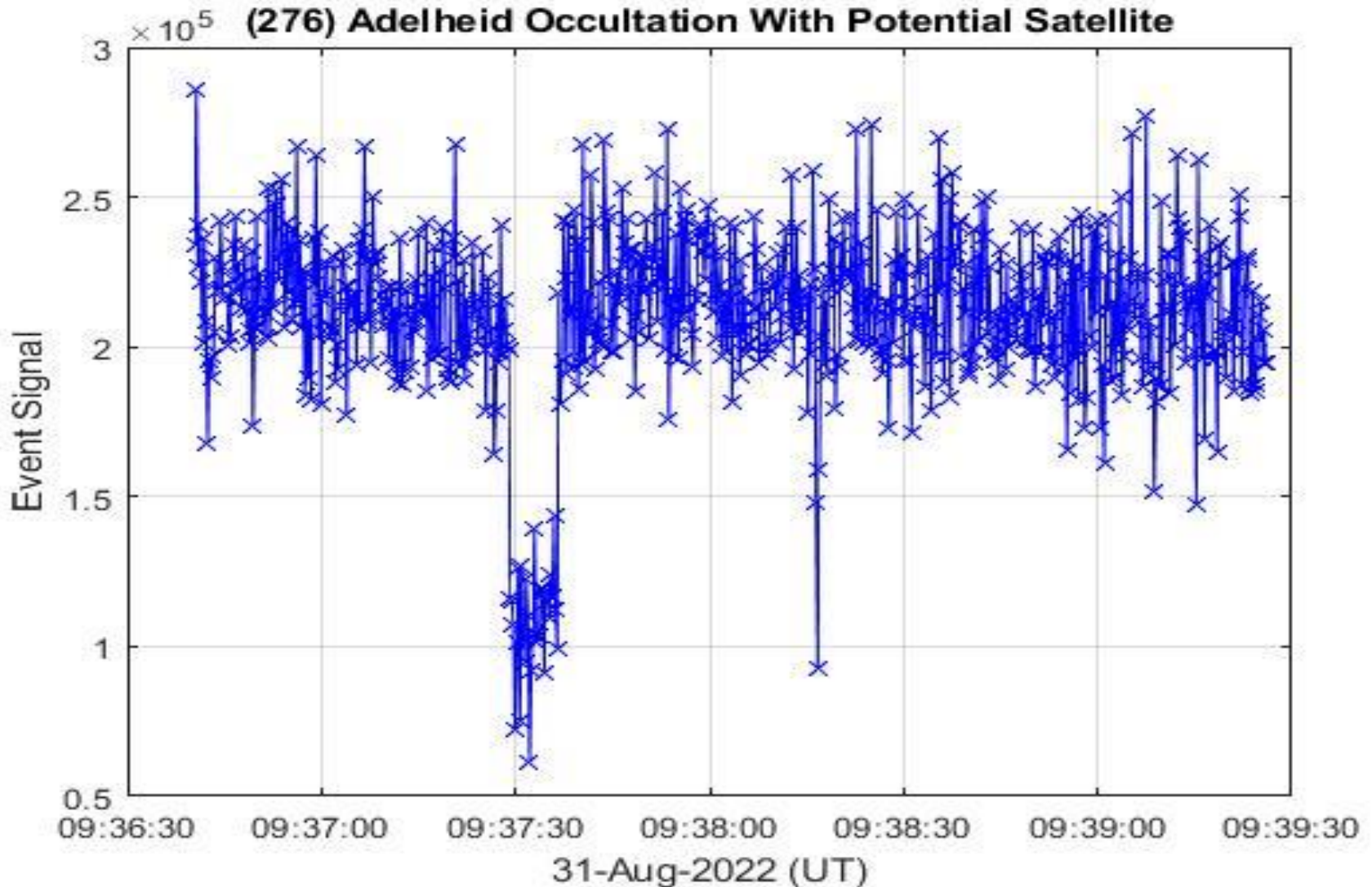


(276) Adelheid Occultation

31-Aug-2022

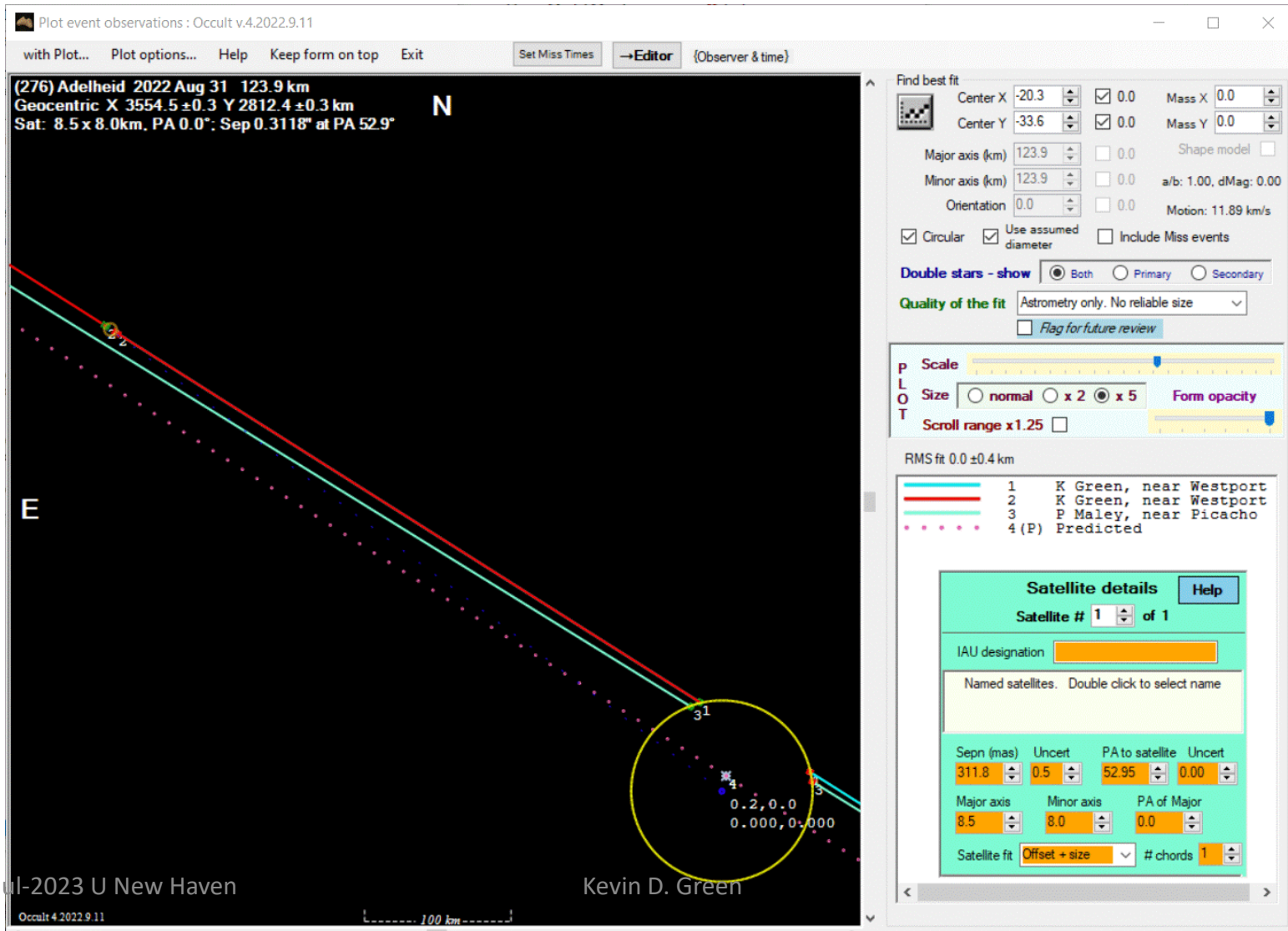


(276) Adelheid From Westport CT

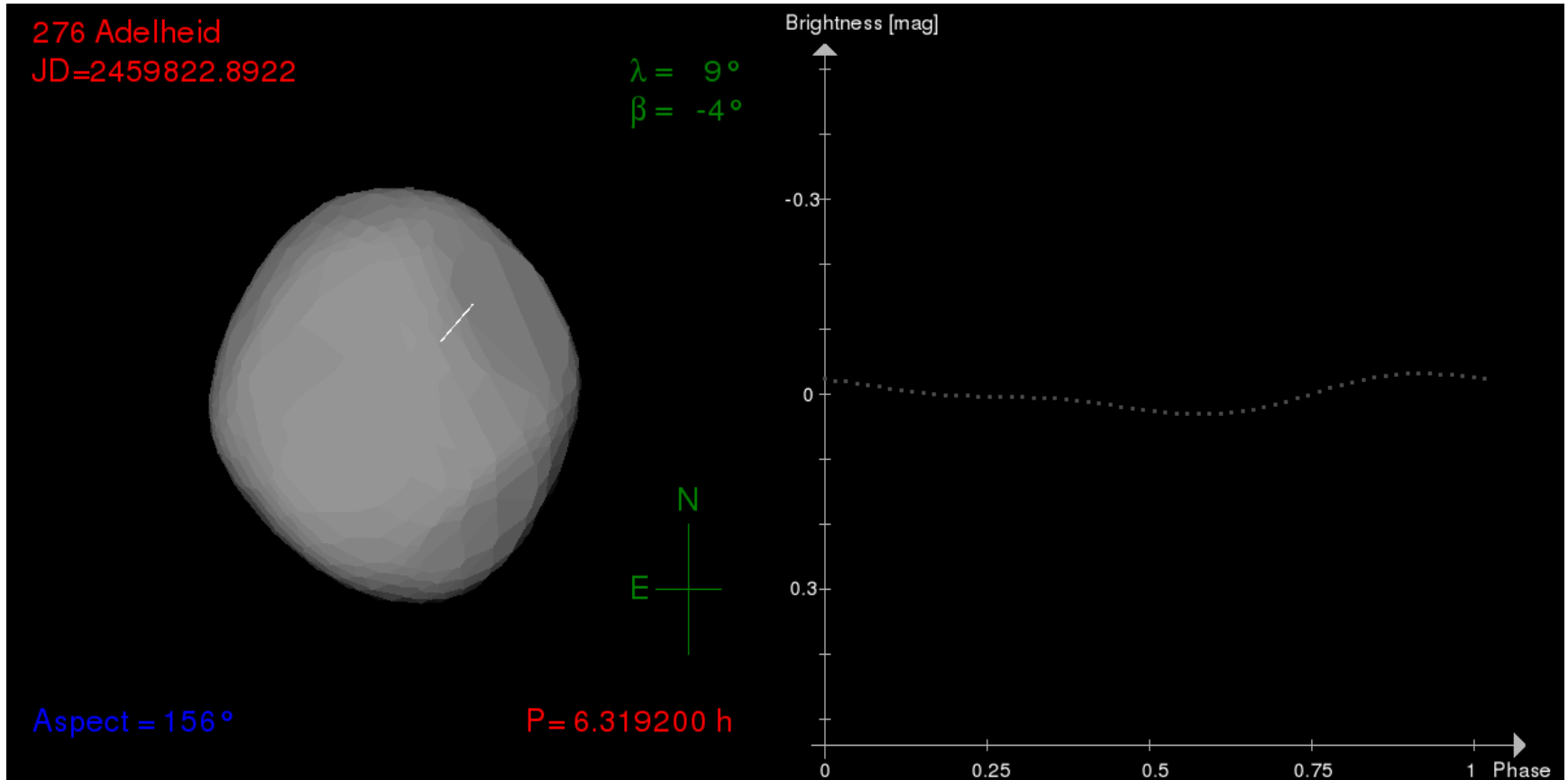


(276) Adelheid: Moonlet

$D \geq 8.5 \text{ km}$, $R_{\text{orb}} = .312''$ (526 km)



31-Aug-2022: Orientation



Satellite Detection: An Unlikely Event

- 8 km segment in 530 km radius circle gives a probability of
$$p = \frac{8 \text{ km}}{2\pi(530 \text{ km})} = 0.0024 (\approx 1 \text{ in } 400)$$
- Magnitude difference (goes as surface area)
- $\frac{I_{Adel}}{I_{sat}} = \left(\frac{125}{8}\right)^2 \approx 244 = (2.511)^{\Delta m}$
$$\Delta m \approx 6$$
- [For $D_{sat}=40 \text{ km}$, $\Delta m = 2.5$]

Adelheid

- Semi-major axis: 3.33 AU (Main Belt)
- Rotation Period 6.328 ± 0.012 hours ($\Delta m=0.1$)
- No mass estimate...Assume:
 - $\rho=2.0$ g/cm³
 - $D=125$ km ($R=75,000$ m)
 - $M=\rho V = 3.5 \times 10^{18}$ kg
- Estimated satellite period (Kepler's 3rd Law):
- $$T^2 = \frac{4\pi^2}{GM} R^3 = \frac{4\pi^2}{(6.67 \times 10^{-11})(3.5 \times 10^{18} \text{ kg})} (530,000 \text{ m})^3$$
- $T = 159,000 \text{ sec} = 44 \text{ hours} = 1.8 \text{ days}$

Adelheid: Past Occultations (15 events, 5 w/ ≥ 3 chords)

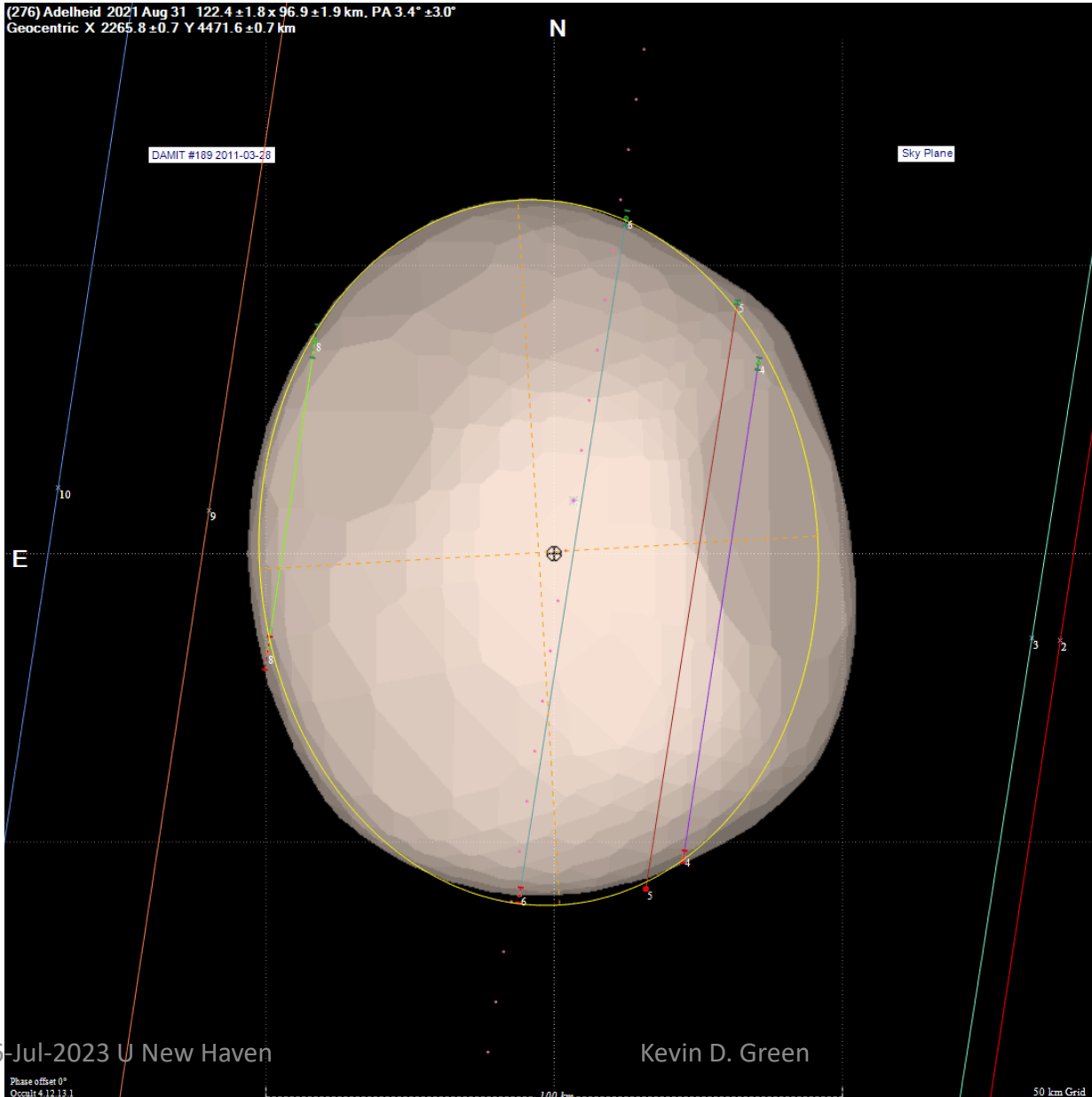
| Date | # Observers | # Hits | Location |
|-------------|-------------|--------|---------------|
| 9-Mar-2002 | 4 | 3 | USA |
| 21-Nov-2012 | 3 | 3 | USA/Australia |
| 12-Dec-2017 | 7 | 5 | Australia |
| 17-Feb-2019 | 12 | 8 | Europe |
| 31-Aug-2021 | 11 | 4 | Europe |

Editorial Comment: The availability of light curves would be beneficial in analyzing past observations.

Presently, none of the posted light curves have evidence for a satellite.

(276) Adelheid: 31-Aug-2021 (Europe) 122x97 km

(276) Adelheid 2021 Aug 31 122.4 ± 1.8 x 96.9 ± 1.9 km, PA 3.4° ± 3.0°
 Geocentric X 2265.8 ± 0.7 Y 4471.6 ± 0.7 km



Find best fit

Center X 4.5 0.0 Mass X 0.0
 Center Y 0.7 0.0 Mass Y 0.0
 Major axis (km) 122.4 0.0 Shape model
 Minor axis (km) 96.9 0.0 a/b=1.26 $v_{lag}=-0.25$
 Orientation 3.4 0.0 Motion 8.69km/s,
 Circular Use assumed diameter Include Miss events

Double stars - show Both Primary Secondary

Quality of the fit Reliable size. Can fit to shape models Flag for future review

p Scale

L Size normal x 2 x 5 Form opacity

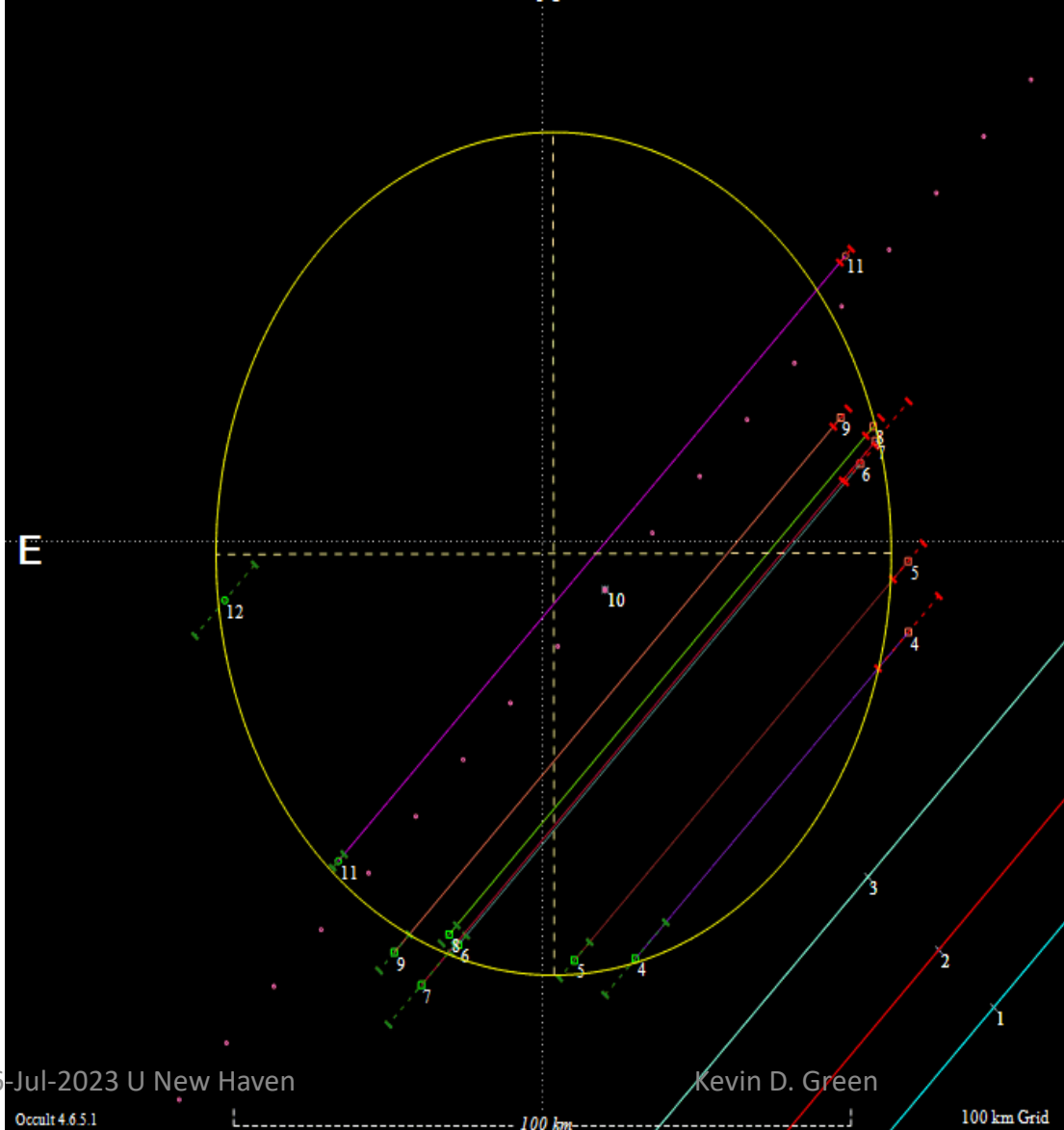
T Scroll range x1.25

RMS fit -0.1 ± 1.1 km

| | |
|--------|--------------------|
| 1 (M) | Anonymous |
| 2 (M) | Anonymous |
| 3 (M) | Harrie Rutten |
| 4 | Anonymous |
| 5 | Fernand Emering |
| 6 | Guenther Neue |
| 7 (P) | Predicted |
| 8 | Anonymous |
| 9 (M) | Anonymous |
| 10 (M) | Patrick Antouly |
| 11 (M) | Anonymous |
| 12 (M) | Jean-Marie Laugier |

(276) Adelheid: 17-Feb-2019 (Europe) 123x109 km

(276) Adelheid 2019 Feb 17 $122.9 \pm 11.8 \times 109.4 \pm 4.9$ km, PA $0.1^\circ \pm 23.7^\circ$
 Geocentric X -504.2 ± 2.5 Y 5551.7 ± 5.3 km



Find best fit

Center X: -2.1 0.0 Centered on Shape model

Center Y: 9.7 0.0

Major axis (km): 122.9 0.1 a/b=1.12

Minor axis (km): 109.4 0.0 dMag=-0.13

Orientation: 0.1 0.0 Motion: 8.26km/s, Y

Circular Use assumed diameter Include Miss events

Double star

Seprn (masec): 0.0 0.0 0 solutions

PA of 2nd: 0.0 0.0 #1 #2 #3 #4

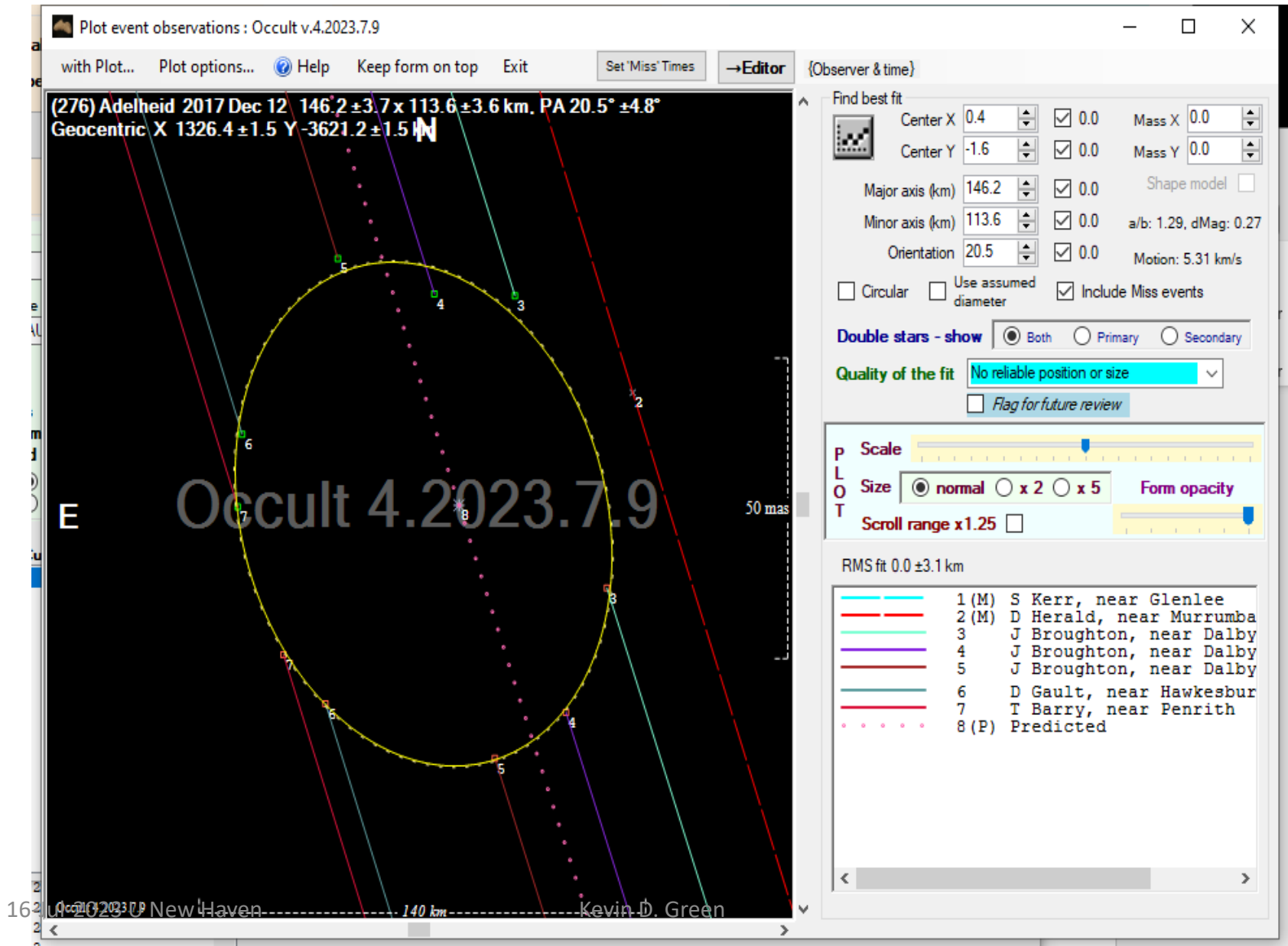
Show: Both Primary Secondary

Plot scale: _____ Quality of the fit: Limits on size, but no shape

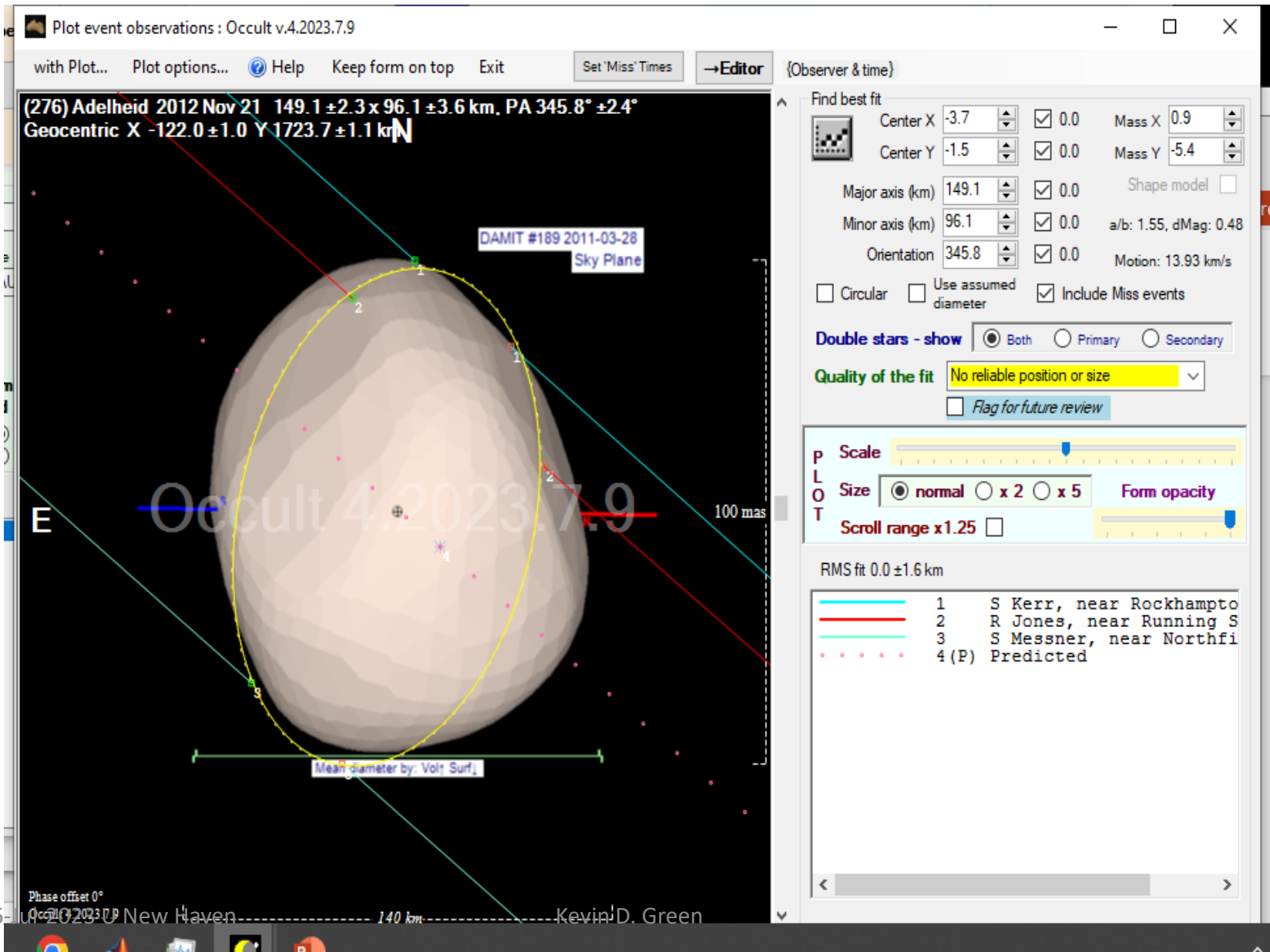
RMS fit 0.2 ± 3.4 km Opacity: _____

| | |
|--------|----------------------|
| 1 (M) | Gerhard Dangl |
| 2 (M) | Tomas Janik |
| 3 (M) | Jan Manek |
| 4 | Jiri Kubanek |
| 5 | Jiri Kubanek |
| 6 | Ladislav Cervinka |
| 7 | Martin Dentel |
| 8 | Peter Lindner |
| 9 | Christian Weber |
| 10 (P) | Prediction |
| 11 | Stefan Gajdos |
| 12 | M. Masek & M. Tylsar |

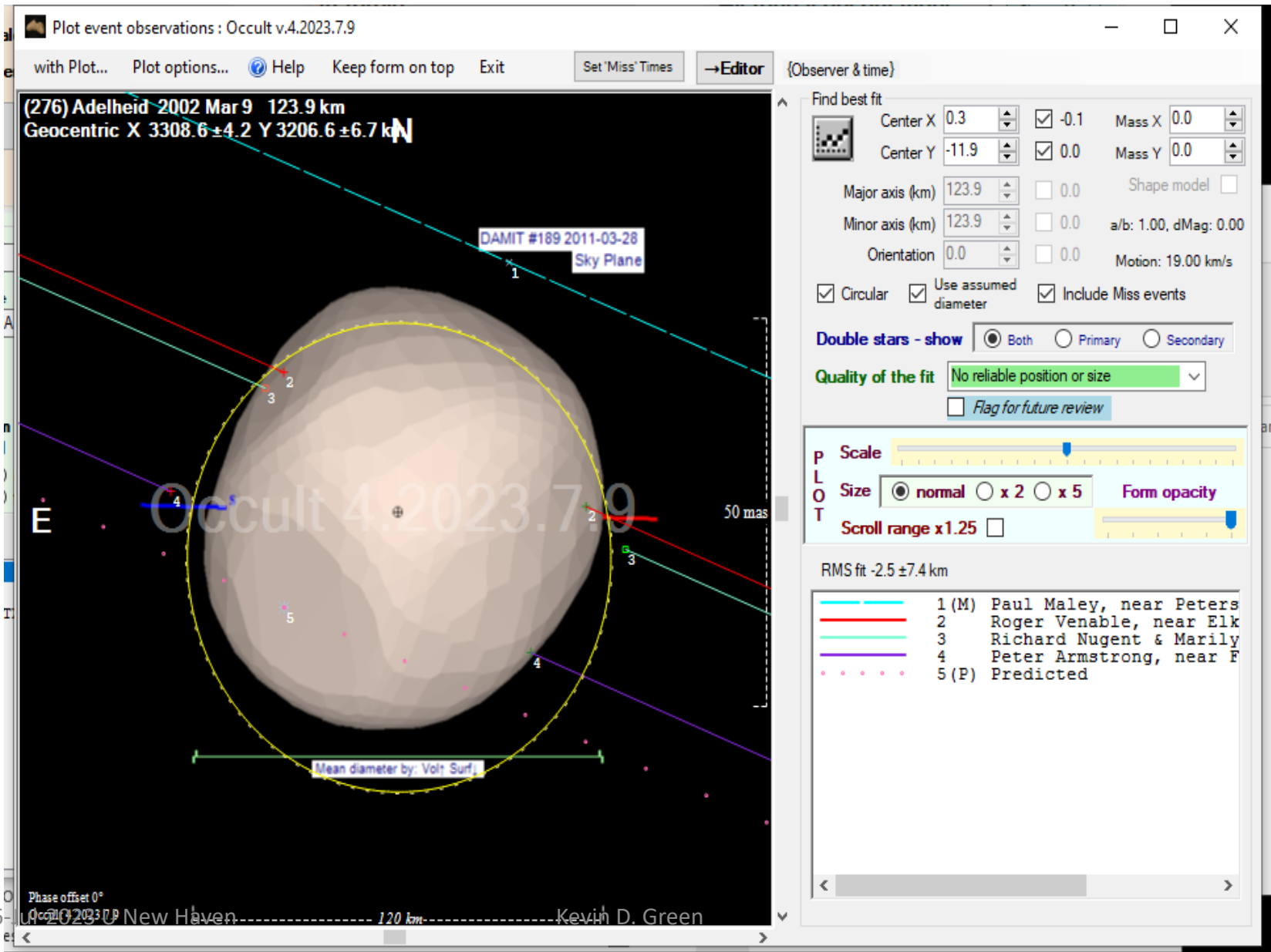
(276) Adelheid: 12-Dec-2017 (Australia) [146x114 km]



(276) Adelheid: 12-Nov-2012 (US/Australia) 145x96km



(276) Adelheid: 9-Mar-2002 (USA) (124 km)

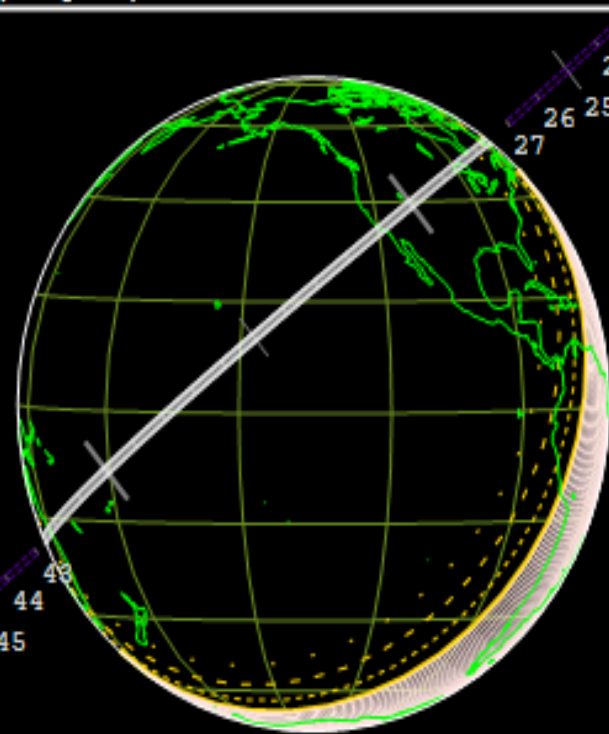


Conclusions From Occultations

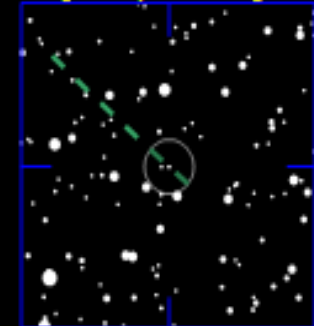
- The shape model conforms reasonably well with the light curves.
 - The Trans-Pacific event (2012) is slightly elongated....
- Data are generally consistent with a near equatorial orbit, but other wilder orbits are not ruled out.
 - Any tidal damping will tend to move the satellite's orbit to one that is equatorial.

2012 Event: Is the stellar duplicity the issue? (Prob not)

276 Adelheid occults UCAC4 459-009916 on 2012 Nov 21 from 10h 28m to 10h 43m U
 Star: (Dia < 0.1 mas) Durations: Max = 9.1 secs Asteroid: (in DAMIT)
 Mv 11.6; Mb 11.8; Mr 11.2 1km = 0.073 secs, 1mas = 0.11 secs Mag = 13.2
 RA = 5 21 29.2200 (astrometric) Mag Drop: 1.8 [81%]v, 1.7 [80%]r Dia = 124 ±6km, 83 mas
 Dec = 1 37 42.303 Sun : Dist = 151° Parallax = 4.294"
 [of Data: 5 22 11, 1 38 25] Moon: Dist = 101°, illum = 59% Hourly dRA = -1.713s
 Prediction of 2023 Jul 10.9 Error 17.0 x 17.0 mas in PA 90° dDec = -21.04"
 Reliable 1.9 (beware), DupSrc, MPCorbINTG:2023 Jun 25, Star+PeakEphemUncert



1° square, to mag 12.6

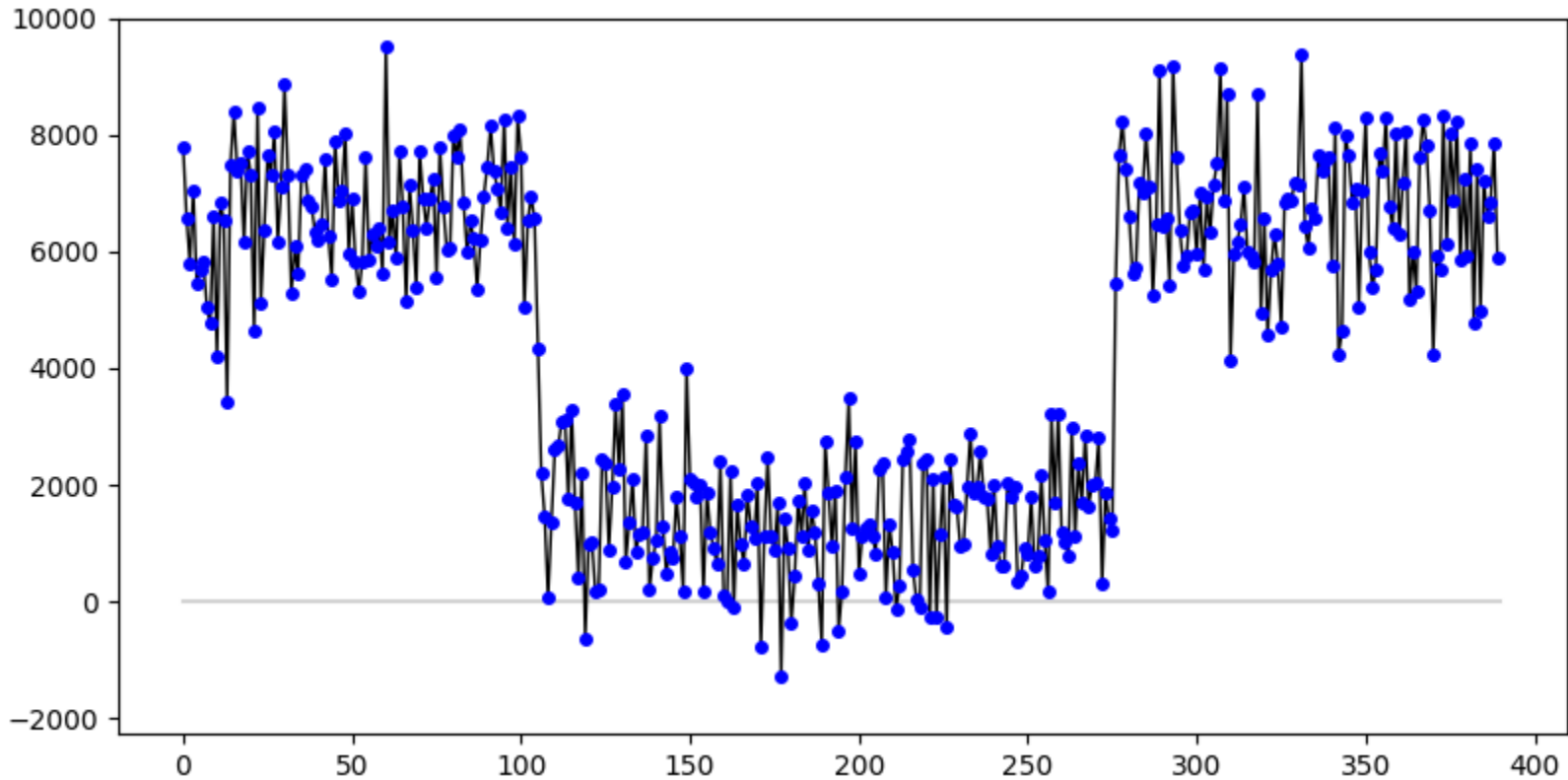


Motion in 6hr steps

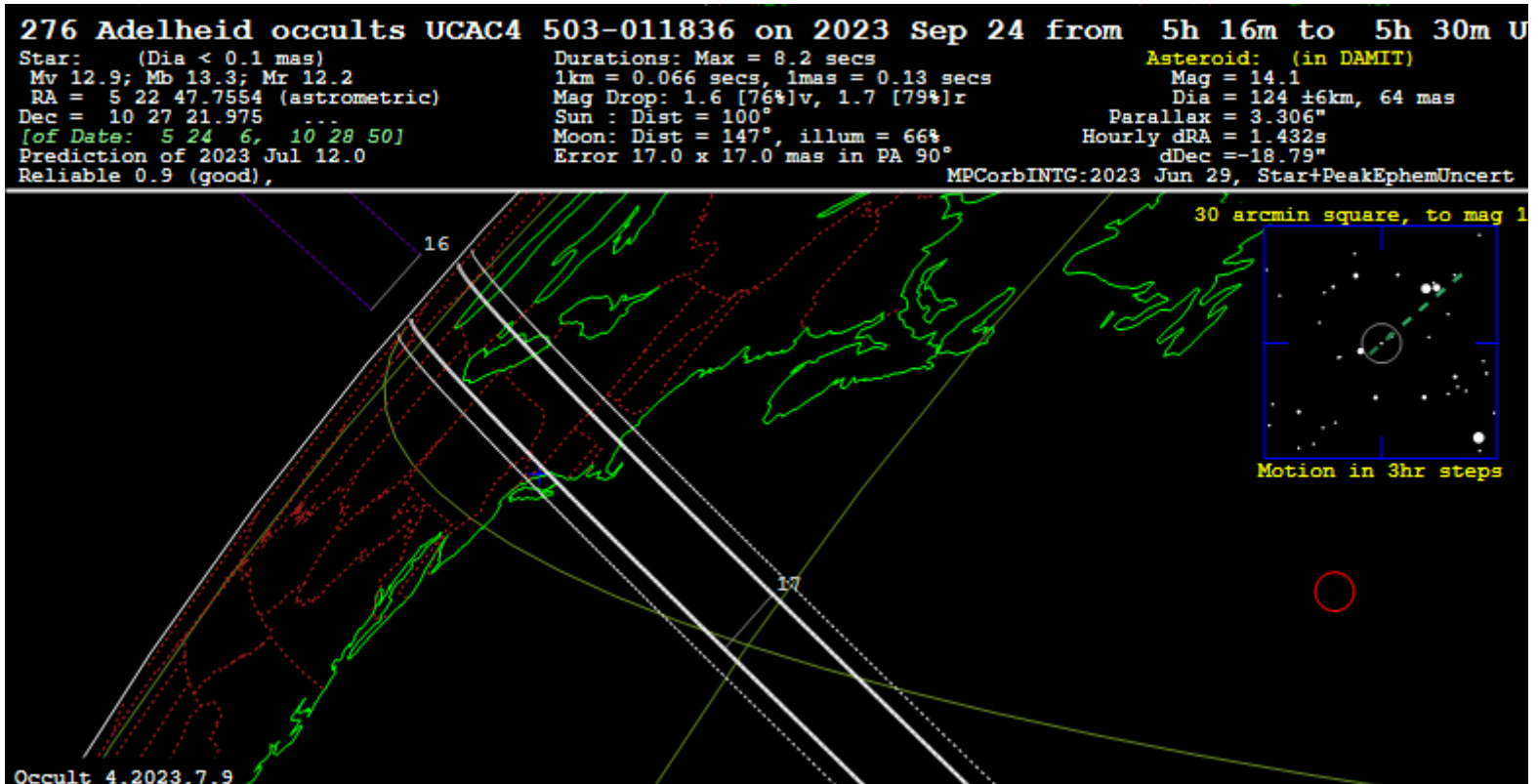
Occult 4.2023.7.9

2012 Adelheid Event

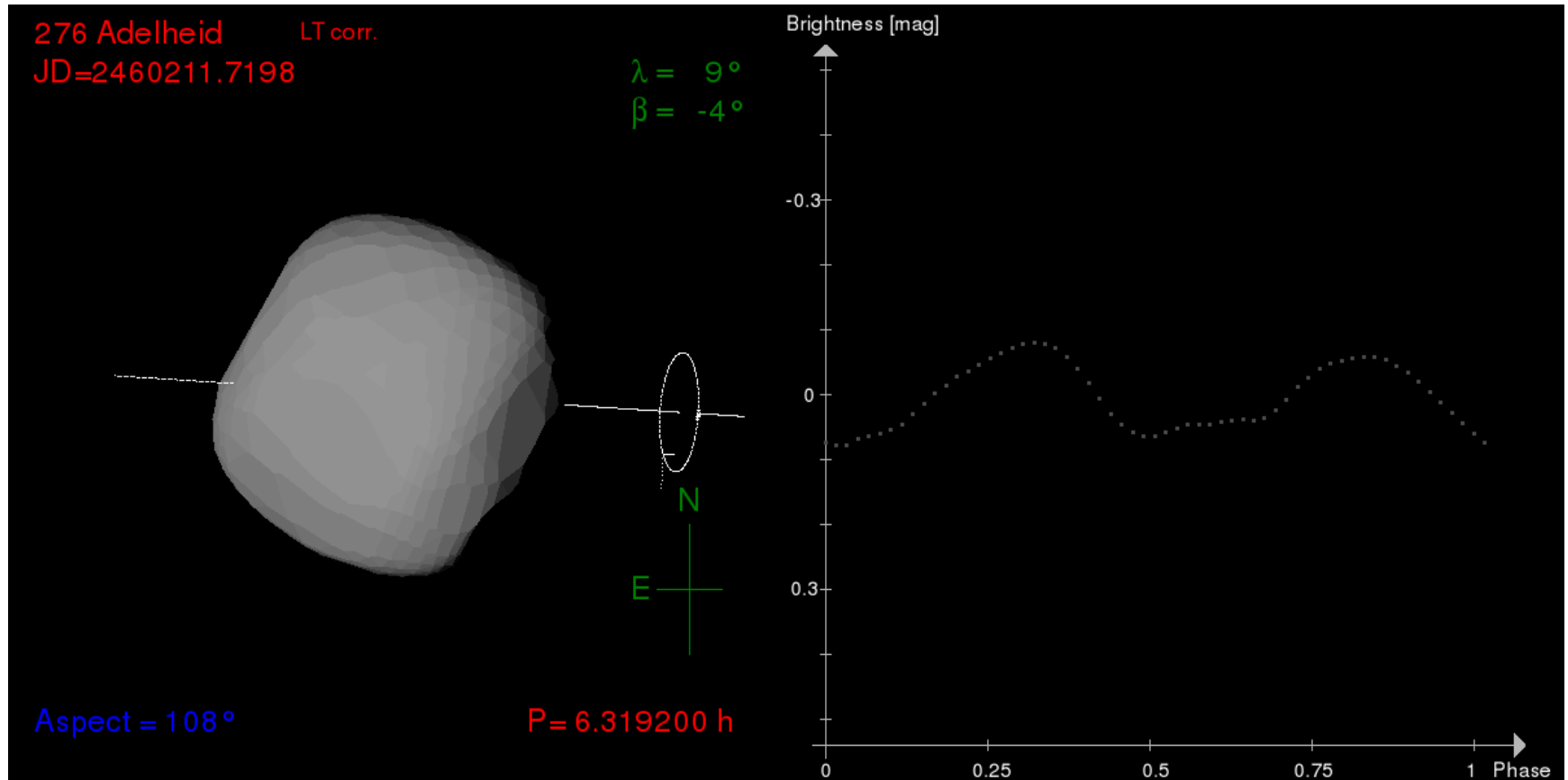
Bob Jones Light curve: Single DR to expected magnitude drop.



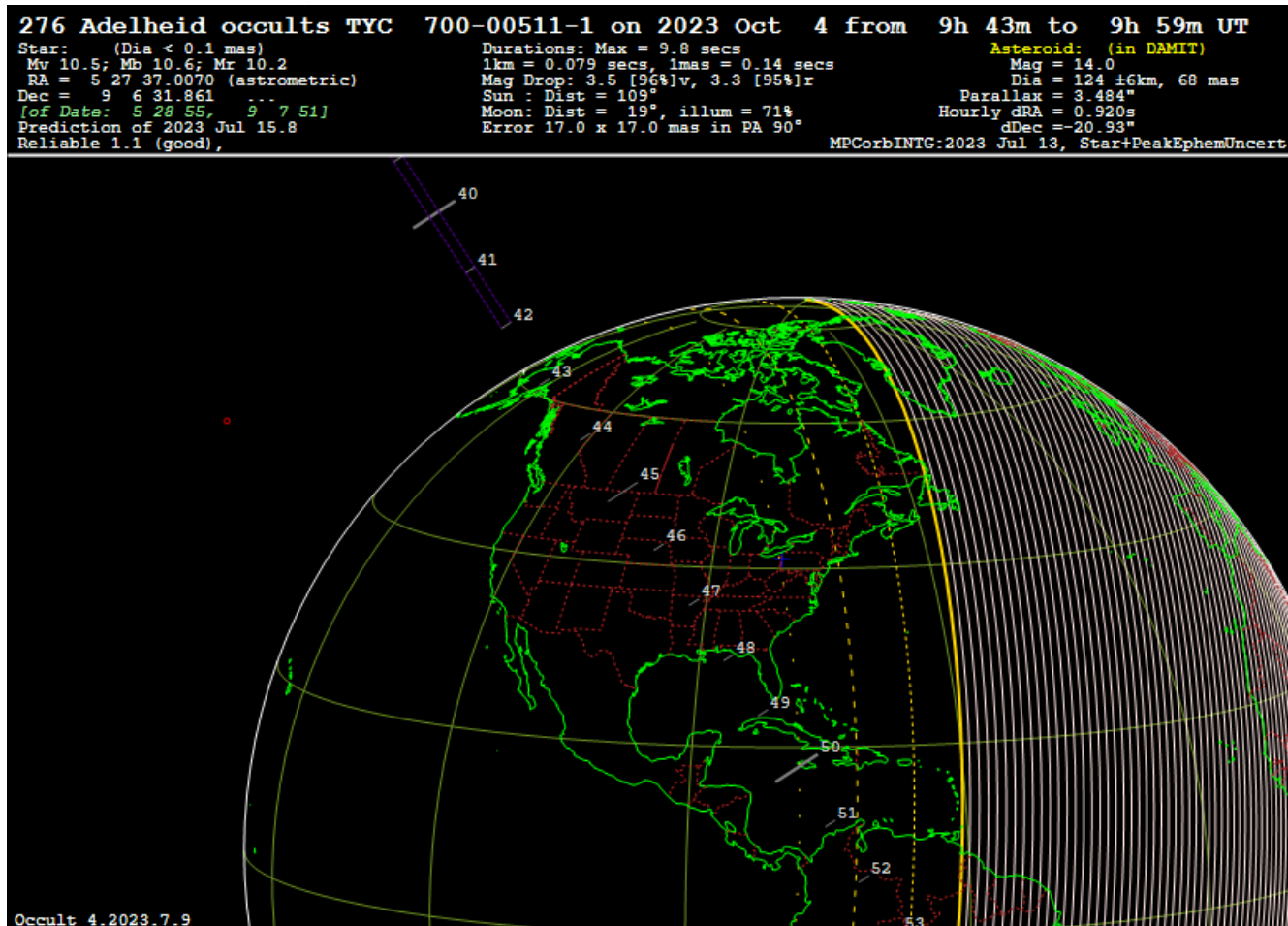
Upcoming Adelheid Events (USA)



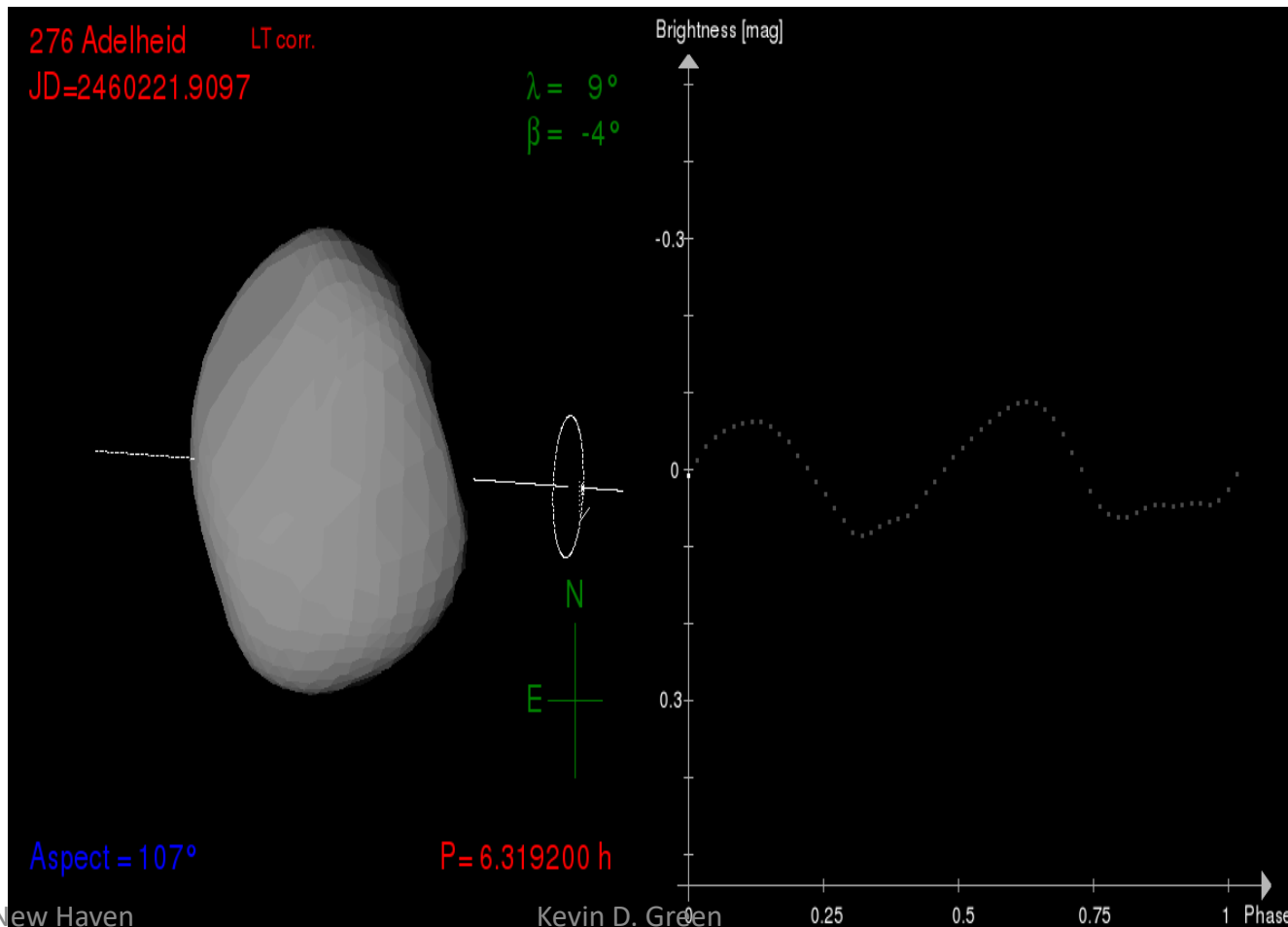
24-Sep-2023: Moon in N-S Orientation Adelheid Silhouette is the Short Axis



4-Oct-2023 Is the Best Opportunity This Year in North America

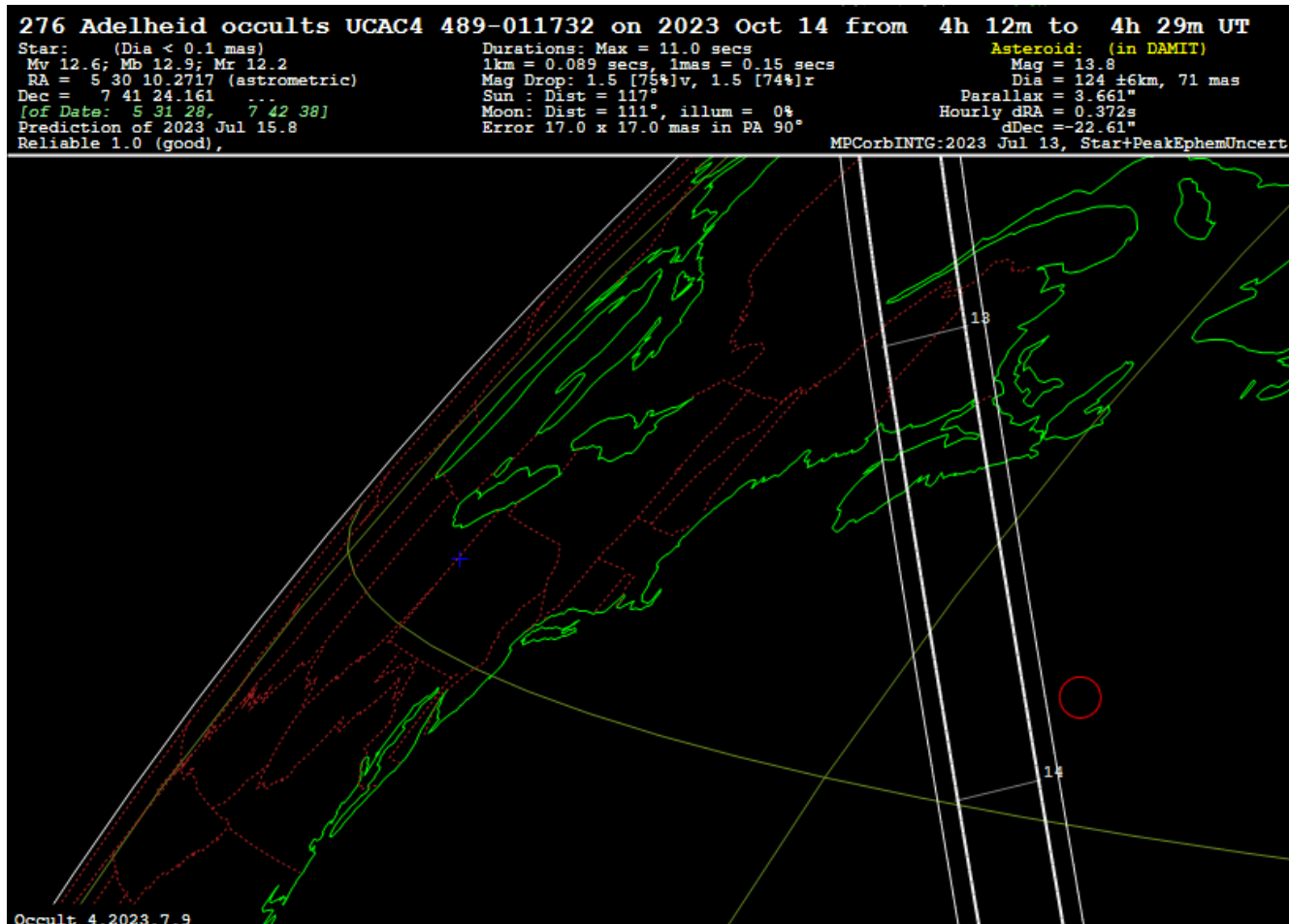


Moon has similar N-S Orientation Shadow Path At Angle Adelheid Longer Silhouette



Maine Anyone?

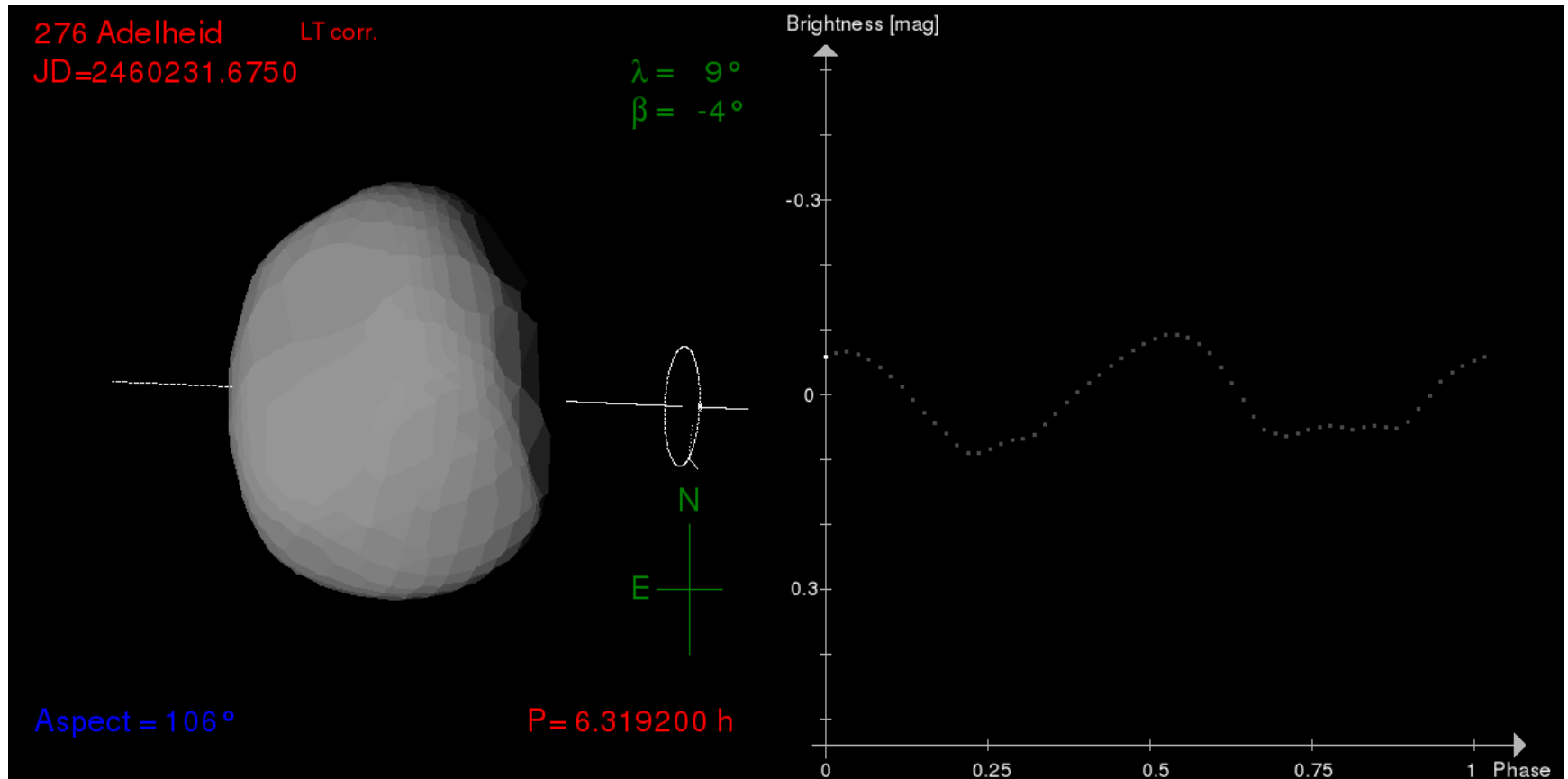
(Equatorial Moon Orbit Well Aligned With Shadow Path)



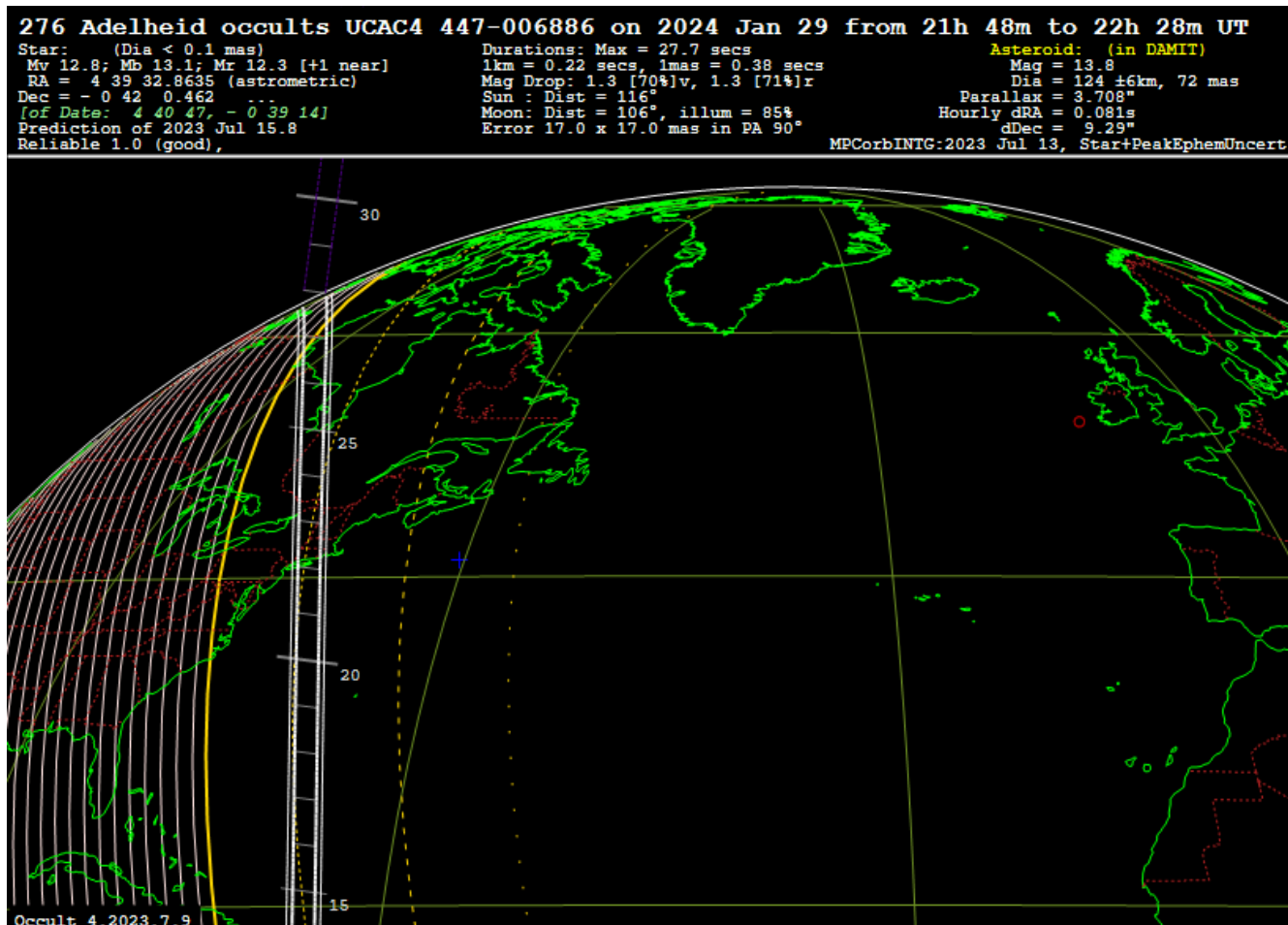
14-Oct-2023 (Thur Even/Fri Midnight)

Moon still N-S Orientation

Adelheid Silhouette Along Long Axis

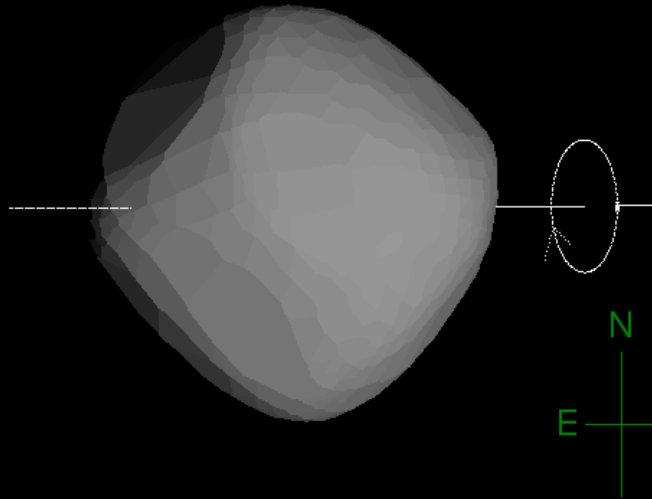


29-Jan-2024: Event In Twilight (Near Stationary Point)



276 Adelheid LT corr.
JD=2460339.4326

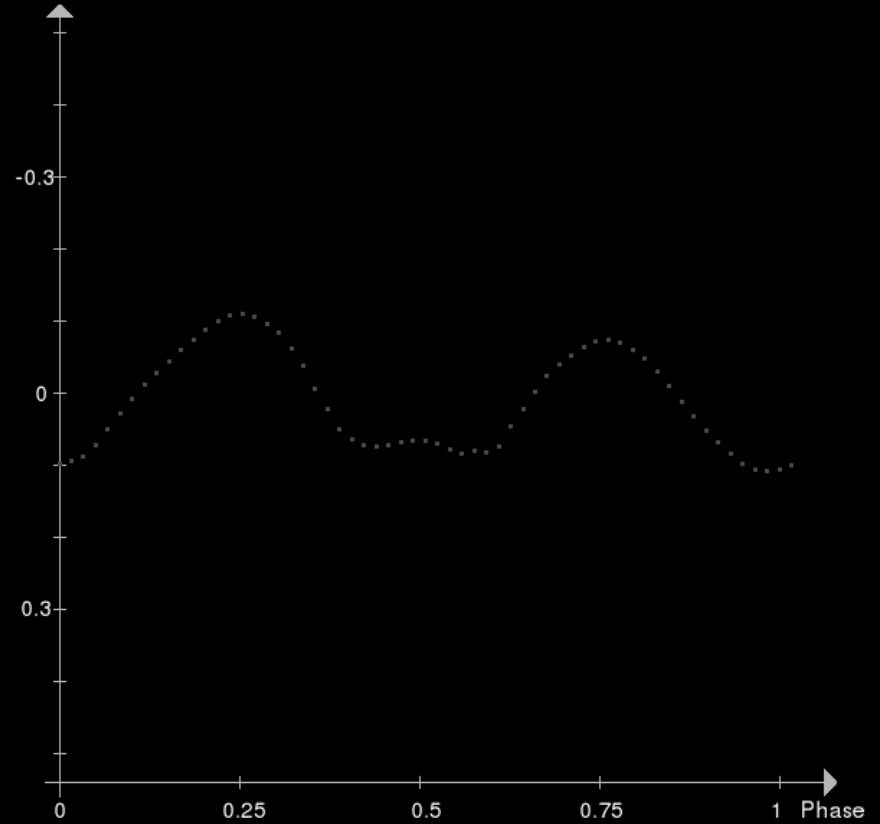
$\lambda = 9^\circ$
 $\beta = -4^\circ$



Aspect = 119°

P = 6.319200 h

Brightness [mag]



Plan Of Action

- Call out to Westport Astronomical Society for help
- Rustling of U New Haven students (very enthusiastic, no experience, no telescopes)
- Call to other local observatories (New Milford, CT)
- Call to other Universities (CT North)
- Hoping for IOTA help (primarily South of CT)

Are We Missing Satellite Events?

- Johnston Asteroids With Satellites: 495

*Asteroids/TNOs with companions by type and level of confirmation
number of systems, with total number of companions in parenthesis*

| type | permanent designation | well-observed | confirmed | probable | total |
|-------------------------|-----------------------|---------------|-----------|-----------|-----------|
| near-Earth asteroids | 0 (0) | 8 (10) | 56 (57) | 29 (29) | 93 (96) |
| Mars crossers | 0 (0) | 0 (0) | 6 (7) | 26 (26) | 32 (33) |
| main belt asteroids | 7 (10) | 8 (9) | 55 (58) | 170 (173) | 240 (250) |
| Jupiter Trojans | 2 (2) | 0 (0) | 2 (2) | 2 (2) | 6 (6) |
| trans-Neptunian objects | 18 (24) | 34 (34) | 19 (19) | 53 (53) | 124 (130) |
| total | 27 (36) | 50 (53) | 138 (143) | 280 (283) | 495 (515) |

- JPL Asteroids With Satellites: 473
- Occult-4: 36

(20426) Fridlund (Oct 2022)

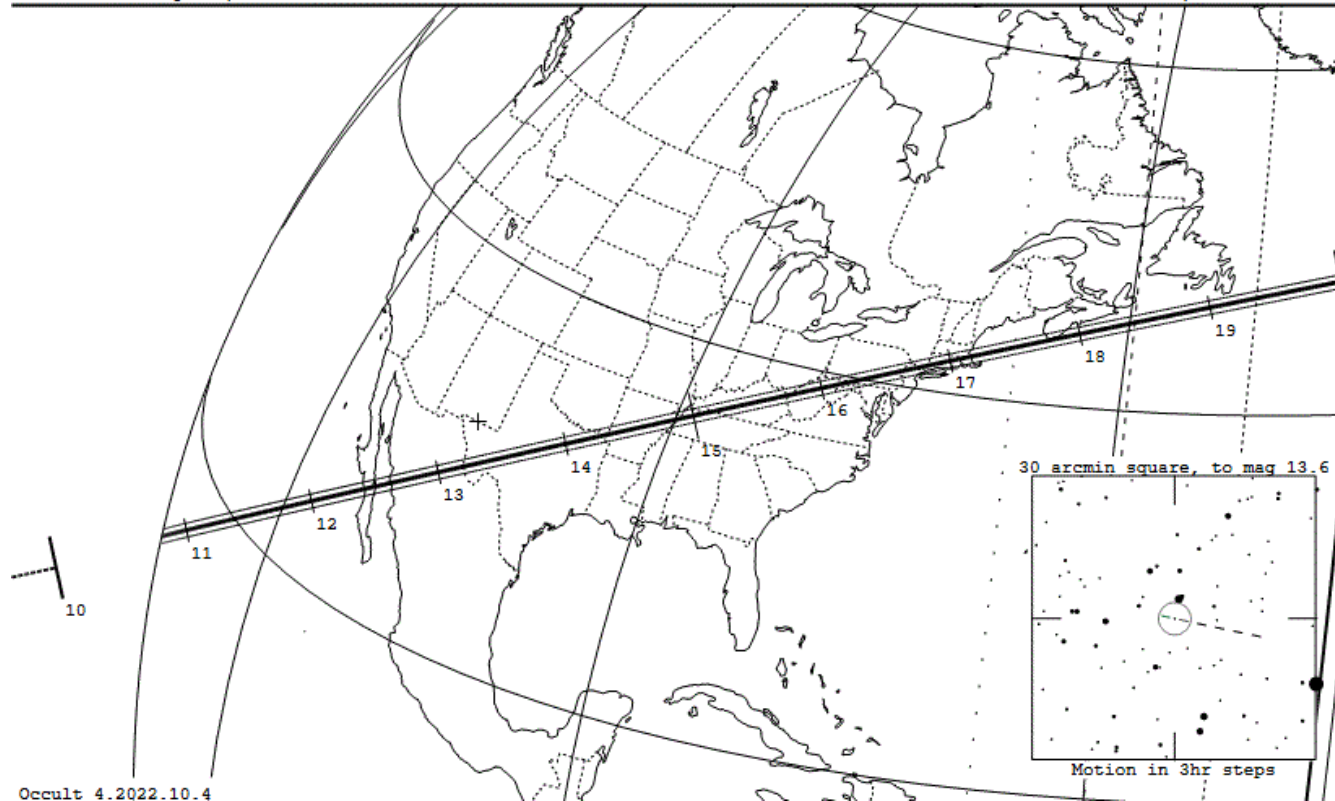
20426 Fridlund occults TYC 1357-00681-1 on 2022 Oct 11 from 9h 11m to 9h 26m UT

Star: (Dia < 0.1 mas)
Mv 12.6; Mb 12.7; Mr 12.3
RA = 7 5 10.1342 (astrometric)
Dec = 20 41 5.800
[of Date: 7 6 30, 20 39 5]
Prediction of 2022 Oct 9.0
Reliable 1.0 (good),

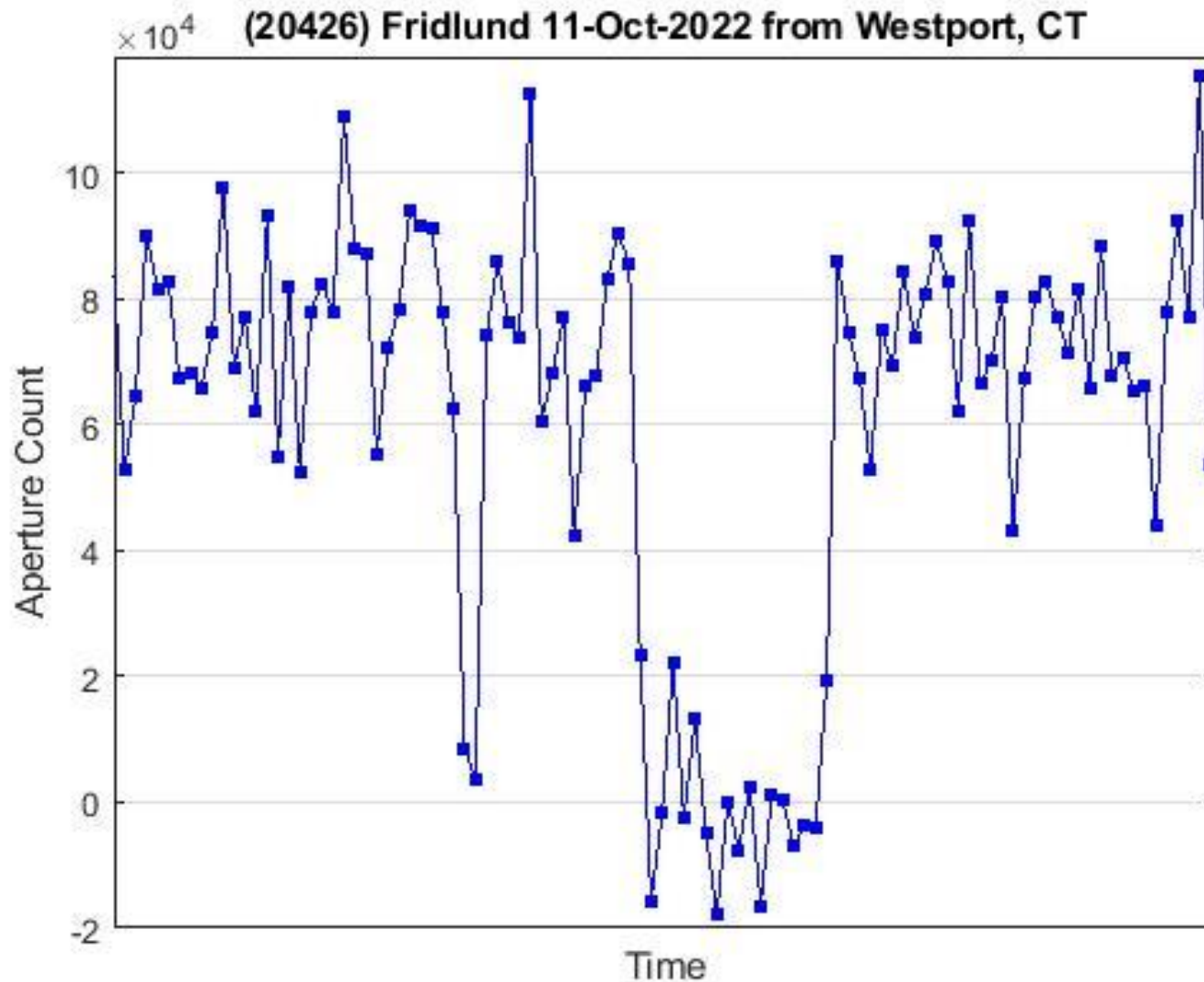
Durations: Max = 0.59 secs
1km = 0.079 secs, 1mas = 0.19 secs
Mag Drop: 6.9 [100%]v, 6.7 [100%]r
Sun : Dist = 93°
Moon: Dist = 69°, illum = 97%
Error 21.3 x 14.3 mas in PA 77°

Asteroid:
Mag = 19.4
Dia = 7.5 ± 0.8km, 3 mas
Parallax = 2.673"
Hourly dRA = 1.336s
dDec = 4.06"

JPL#40:2022-09-23, Known errors



Another one?



Summary

- From last year's occultation there is good evidence for a satellite of (276) Adelheid. Confirmation is required.
- While limited, a few events are possible in North America this year (and 1-2 also in Europe).
- (276) Adelheid shape from occultations are in reasonable agreement with the inverted light curve shape, but some disagreements exist.
- Is there a need for a dedicated effort related to asteroid satellite predictions and analysis of possible detections?