Improvement of Asteroid Orbits for and with Asteroidal Occultations

Updated 2020 Aug. 28 for ESOP-39

A splinter meeting at JPL from the NASA Small Bodies Assessment Group, Pasadena, California 2020 January 15

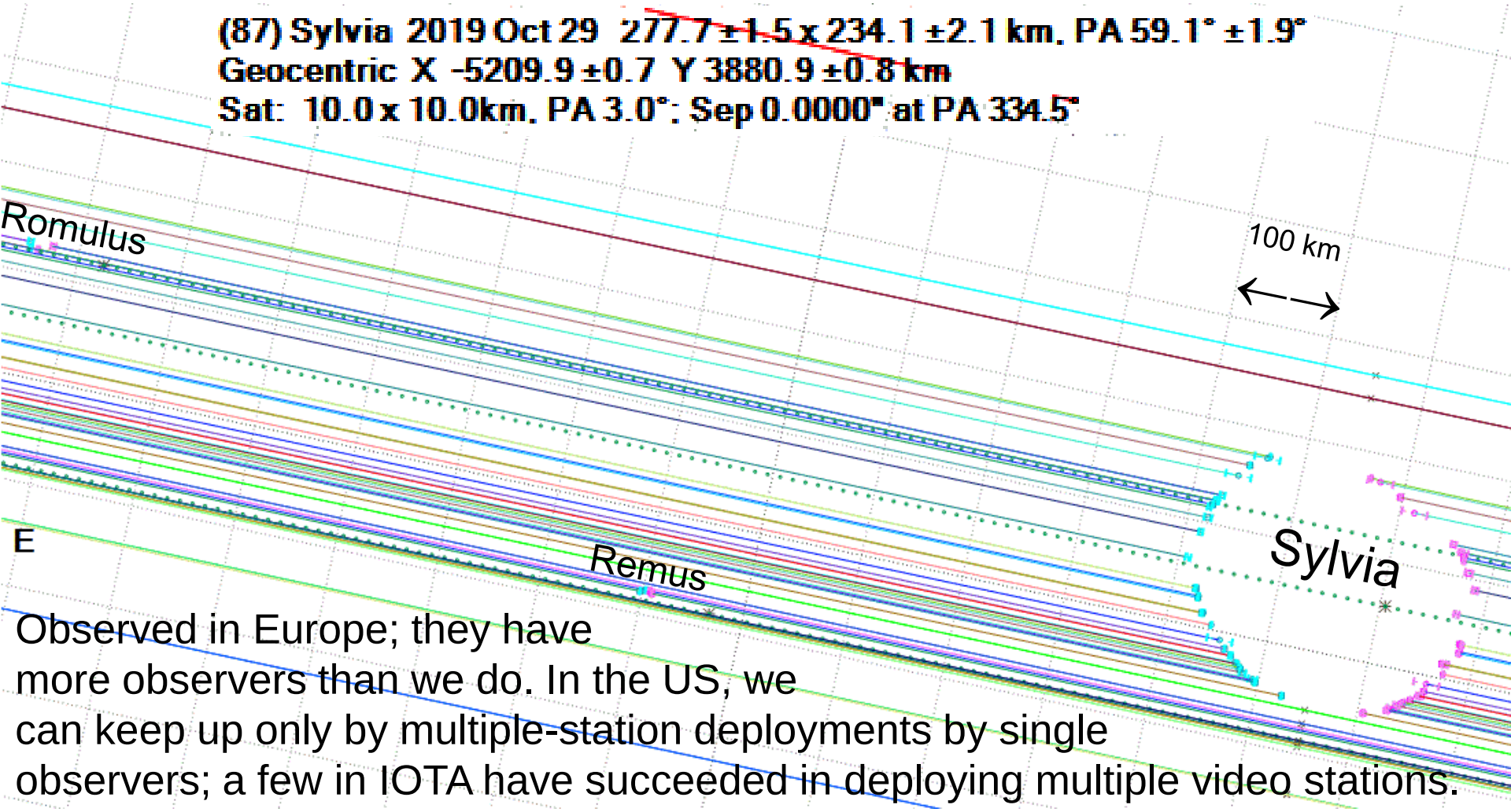
D. W. Dunham[1&2], J. B. Dunham[1], M. Buie[3], S. Preston[1], D. Herald[1], D. Farnocchia[4], J. Giorgini[4], R. Park[4], P. Chodas[4], J. Moore[1], T. Pauwels[5], P. Tanga[5] (underlined attended, at least remotely

[1]International Occultation (IOTA, P. O. Box 423, Greenbelt, MD 20768, USA, iotatreas@yahoo.com), [2]KinetX Aerospace (david.dunham@kinetx.com), [3]Southwest Research Inst., Boulder, CO, [4]Jet Propulsion Lab., [5]Gaia Consortium

Outline

- Observing Occultations, a Quick Introduction
- Improving Orbits for Asteroidal Occultations
- The 2019 Phaethon Occultations
- Others improved with Gaia: Pandora & Tirela
- SwRI Occultations by Arrokoth and Leucus
- Further Improving Orbits with Asteroidal Occultation Observations
- NEO Occultations – How Small?
- Future Occultations Needing Improvement
- Need some modifications, from previous presentation (Ferreira, Tanga, and Machado; related work)

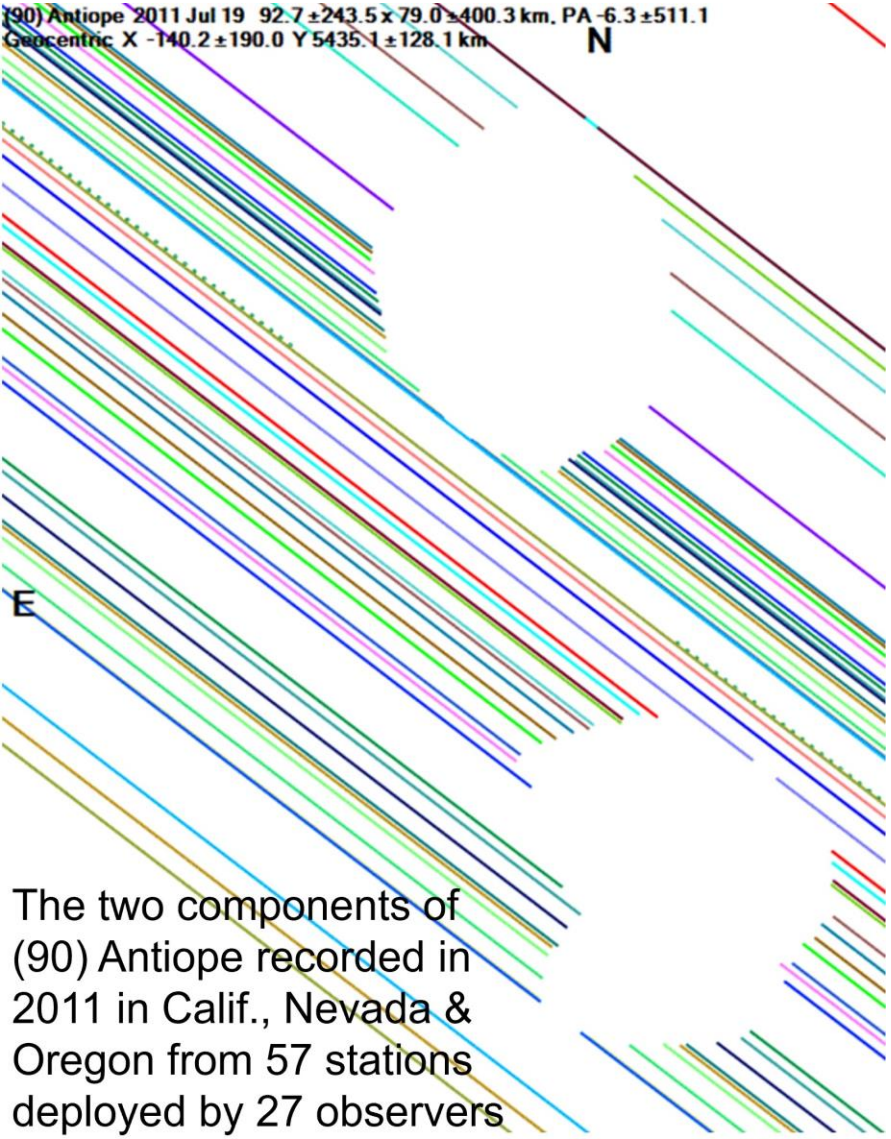
Observing Occultations, a Quick Introduction



Observed in Europe; they have more observers than we do. In the US, we can keep up only by multiple-station deployments by single observers; a few in IOTA have succeeded in deploying multiple video stations.

Worldwide total # of occultations – 4361 (as of late 2019)
By chords: 1 only – 2660, 61%; 2+ 2110; 3+ 924; 5+ 397; 10+ 91
By separation accuracy: <1mas 554; <2mas 1044; <3mas 1288

I had a poster presentation about multi-station deployments at ESOP-38 in Paris last year.



The two components of (90) Antiope recorded in 2011 in Calif., Nevada & Oregon from 57 stations deployed by 27 observers

The star was red giant LQ Aquarii; the angular diameter was found to be 2 mas from the gradual D's and R's that were recorded.

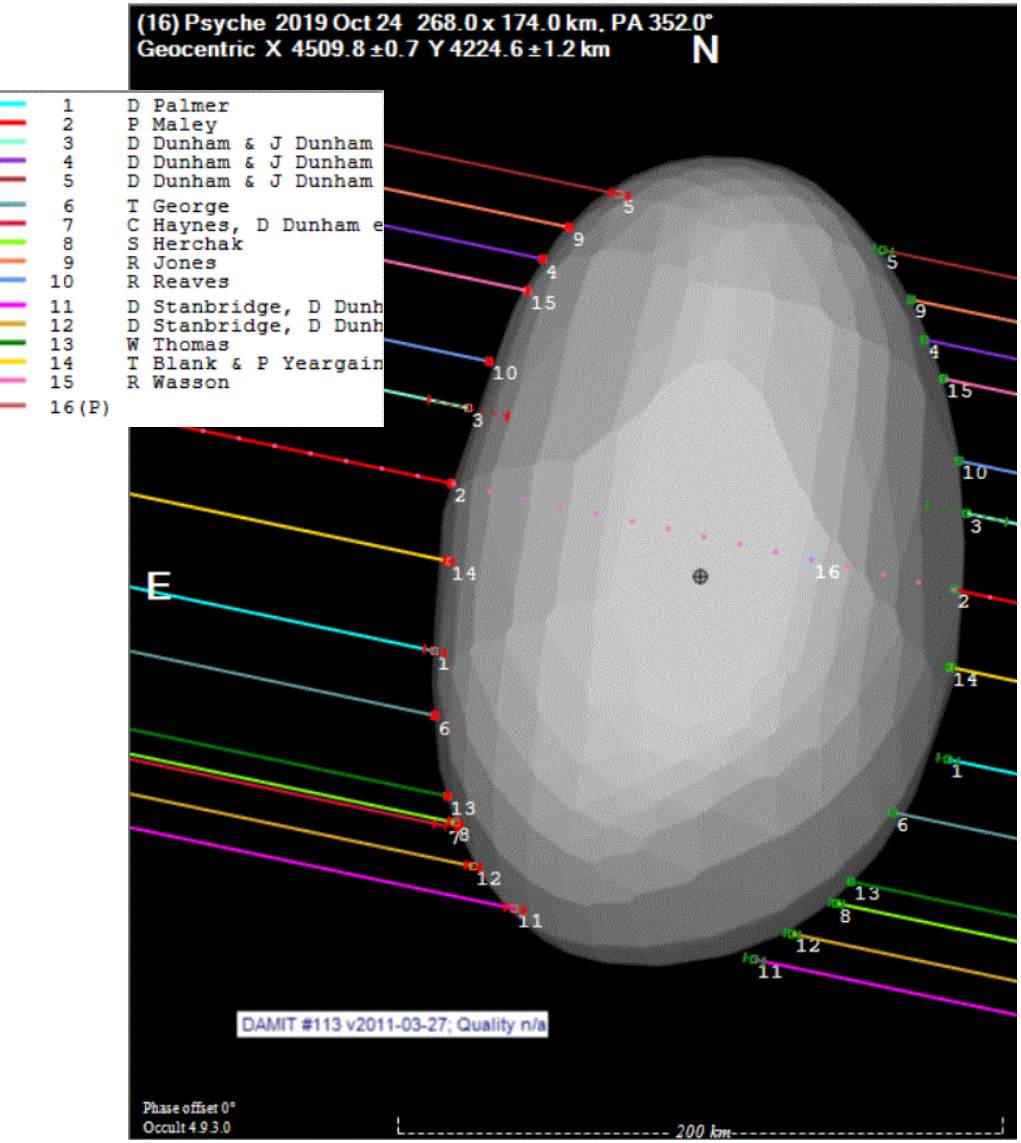
John Broughton described his specialized occultation scopes for multi-station efforts at TTSO 2020, 10th at http://www.occultations.org.nz/meetings/TTSO14/Schedule.htm

A remote station pre-pointed night before on paver stone

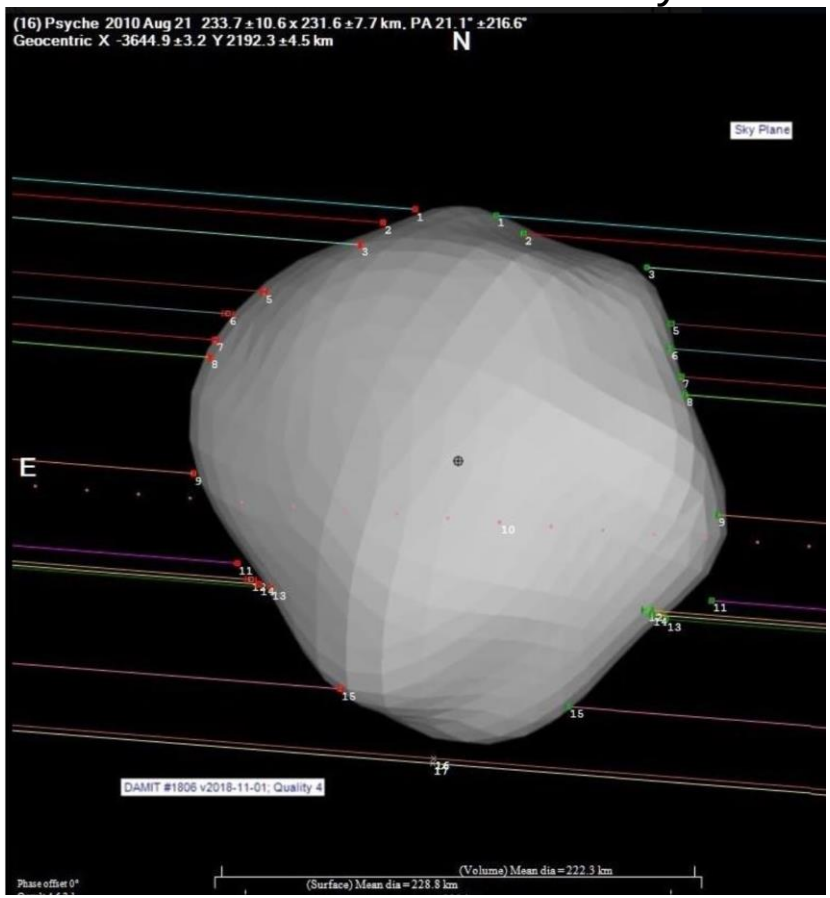
80mm "midi" refractor with orange IOTA Runcam camera and a stick iView miniPC to record. An IOTA-VTI provides accurate time. This "paver-mount" station was pre-pointed on the 1-foot square paver stone shown the night before the occultation, removed from the paver stone, then returned to it the afternoon before the occ'n night. The paver stone is marked with a sharpee for accurate scope placement. The system can record stars to mag. 11.0. More about a multiple paver-mount success is in Journal of Occultation Astronomy (JOA), 2019 issue #1, pp. 3-8. IOTA's JOA is available for free .pdf download at http://occultations.org/pub/newsletters/ .

Occultation of 10.2-mag. Star by (16) Psyche, 2019 Oct. 24, s.w. USA

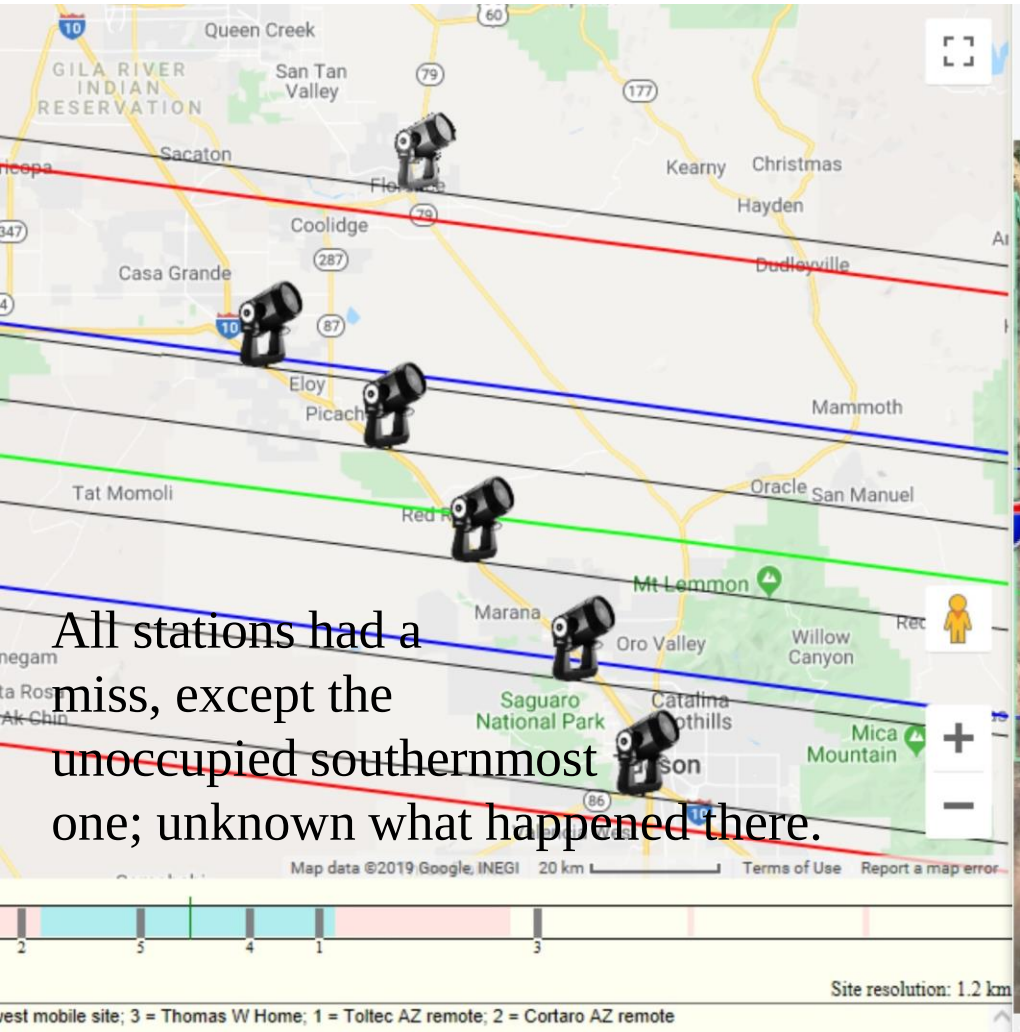
- For the recent event, we have an excellent fit of the 15 well-spaced observations with DAMIT shape model 113. But another well-observed occultation in 2010 (below) fits well with model #1808, and neither model fits the other occultation. So more work is needed on the Psyche shape models.



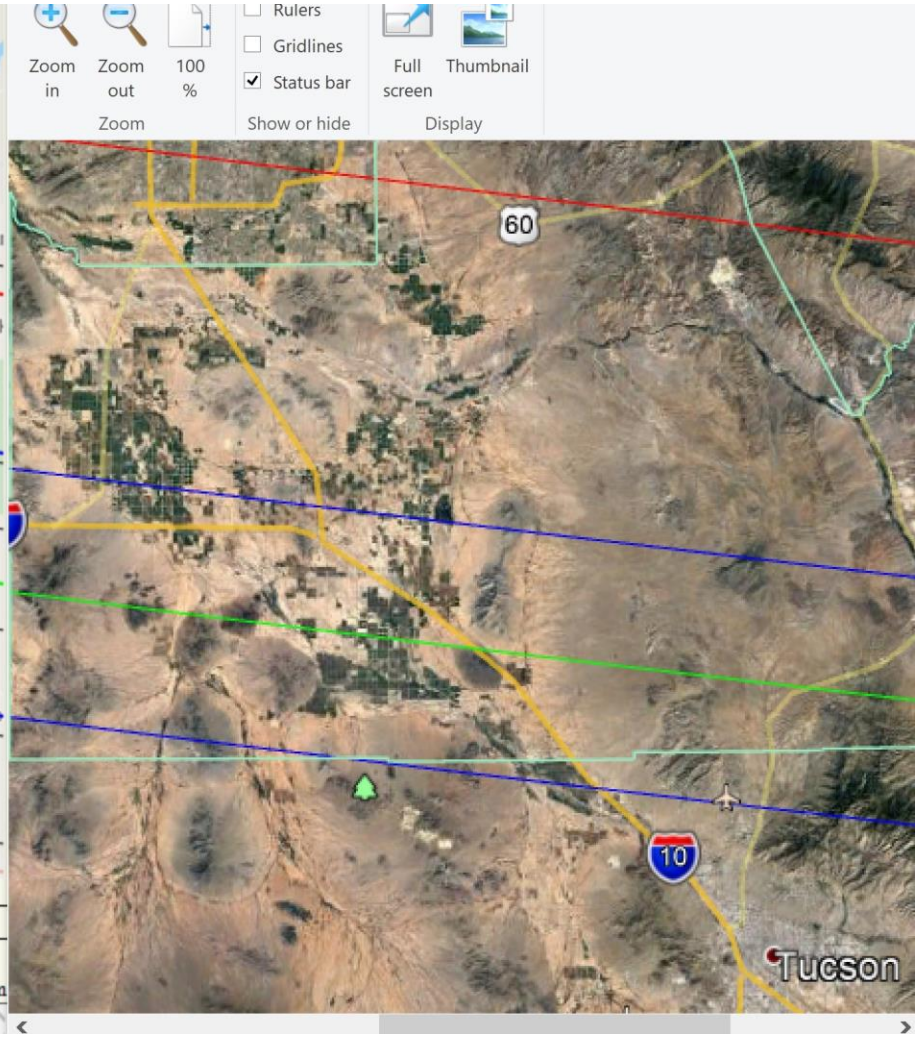
2010 Aug. 21 Psyche occultation, observed from Texas to Maryland



Failure to obtain a positive for 2019 Dec. 17 (1409) Isko occultation; possibly a 2-sigma shift (no problems with the Gaia DR2 star data)



All stations had a miss, except the unoccupied southernmost one; unknown what happened there.



Preston's prediction is on the left; the JPL Horizons prediction on the right was only a few km farther north. European and UK observers had a similar experience with a 2020 Jan. 7th occ'n by (456) Abnoba, but RUWE was high.

Improving Orbits for Asteroidal Occultations

- Observations increased greatly with 1997 HIP DR
- Starting 1999, occ'n astrometry reported to MPC by Dave Herald, but MPC still doesn't pass on our accuracies
- Great improvement with Gaia DR1, then DR2, but for stars only
- Several successes by using a 1st observed occ'n in an apparition to improve later occ'ns (Gaia stars good) – Discussed that in JOA 2018-4, p. 6

(3200) PHAETHON, FIRST SUCCESSFUL OBSERVATIONS OF OCCULTATIONS BY A SMALL NEAR-EARTH OBJECT

Paper 2062 [<u>but a separate IOTA talk, so less here</u>]

Abstract submitted for an AAS-DPS presentation

Asteroid Science in the Age of Hayabusa2 and OSIRIS-REx, Tucson, Arizona, 2019 November

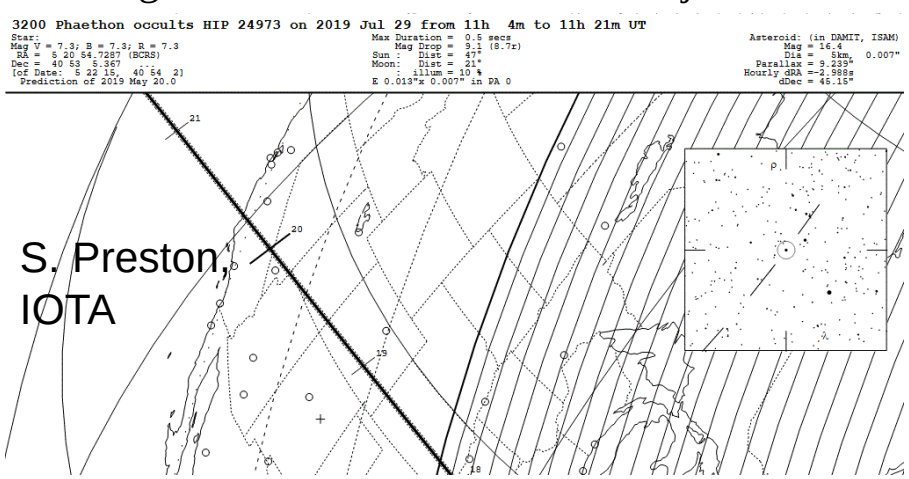
D. W. Dunham[1&2], J. B. Dunham[1], M. Buie[3], S. Preston[1], D. Herald[1], D. Farnocchia[4], J. Giorgini[4], J. Irwin[1], D. Breit[1], L. Wasserman[5], S. Marshall[6], T. Arai[7], F. Yoshida[7], I. Sato[8], H. Noda[9], M. Sôma[9], J. Moore[1], S. Degenhardt[1], R. Nolthenius[1,10], A. Verbiscer[11], M. Skrutskie[11], M. Nelson[11], P. Tanga[12], J. Ferreira[12], D. Vernet[12], J.P. Rivet[12], E. Bondoux[12], E. Frappa[13], T. Hayamizu[14] , Q. Ye[15], D. Baba Aissa[16], Z. Grigahcene[16]

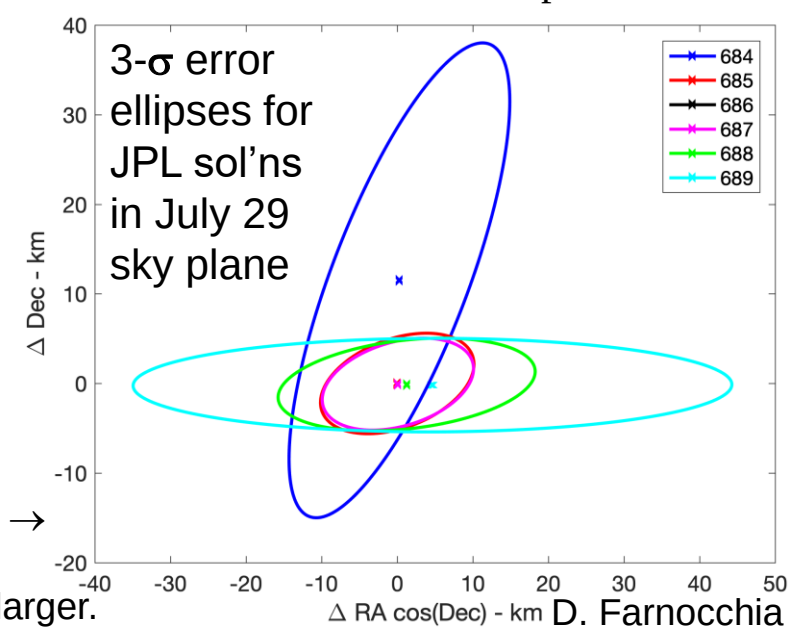
[1]International Occultation (IOTA, P. O. Box 423, Greenbelt, MD 20768, USA, iotatreas@yahoo.com), [2]KinetX Aerospace (**david.dunham@kinetx.com**), [3]Southwest Research Inst., Boulder, CO, [4]Jet Propulsion Lab., [5]Lowell Obs., [6]Arecibo Obs., [7]Planetary Exploration Res. Ctr. (PERC), Chiba Inst. of Tech., Japan, [8]PERC collaborator, [9]Japanese National Astronomical Obs., [10]Cabrillo College, Santa Cruz, CA, [11]Univ. of Virginia, [12]Obs. de la Côte d'Azur, [13]www.euraster.net, [14]Saga Hoshizora Astron. Ctr., Japan, [15]Caltech, [16]Algiers Obs. - CRAAG

Updated 2019 November 2x

THE 2019 JULY 29 OCC'N OF 7.3-MAG. SAO 40261 BY PHAETHON

- This event was first identified by Isao Sato in Japan. In January 2019, he alerted US observers via a message that he sent to the IOTAoccultations list server.
- To obtain an accurate astrometric point for orbit improvement, and to resolve the diameter discrepancy, Tomoko Arai, PI of DESTINY+, requested that NASA & IOTA try to observe the rare bright July 29th occultation by Phaethon in the s.w. USA.
- This was by far the smallest object that IOTA had tried to predict and observe; we needed help.
- Those who predicted this occultation, and analyzed the observations of it, all had to modify their software, to take into account previously-neglected effects that weren't significant for occultations by all of the larger objects studied in the past. Even the difference in the gravitational bending of light by the Sun, for the star and Phaethon, was noticeable.
- Jon Giorgini computed JPL solution 684 after including radar measurements made in 2017. Then Davide Farnocchia computed JPL 685, manually including Gaia astrometry; this was key.
- Adding new astrometric observations just confirmed JPL 685, so it was used for the final prediction.



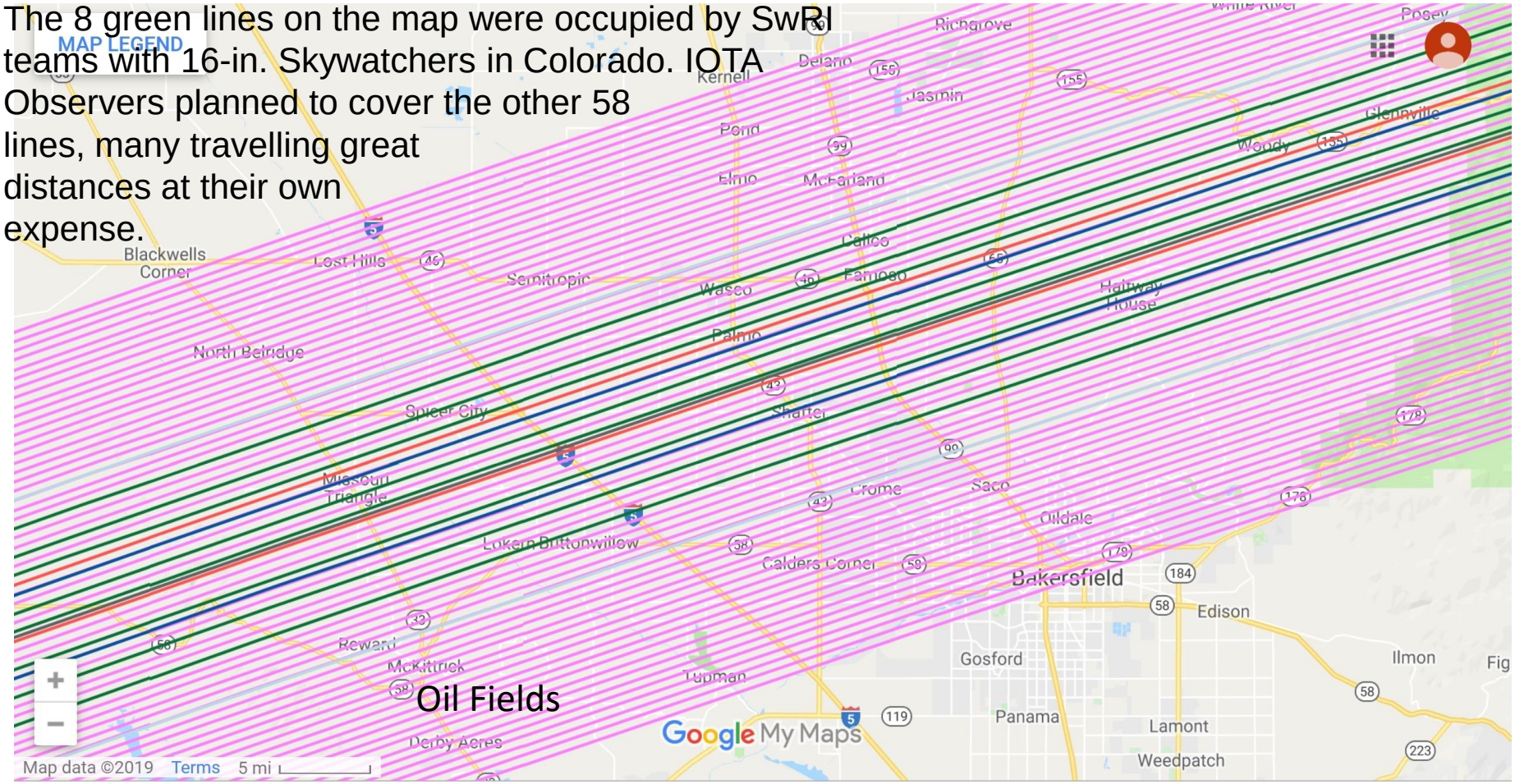


Phaethon's motion was from lower left to upper right, → so the 3σ limits (JPL 385) were 8 km + Phaethon's radius from center; the ground projection was a little larger.

D. Farnocchia

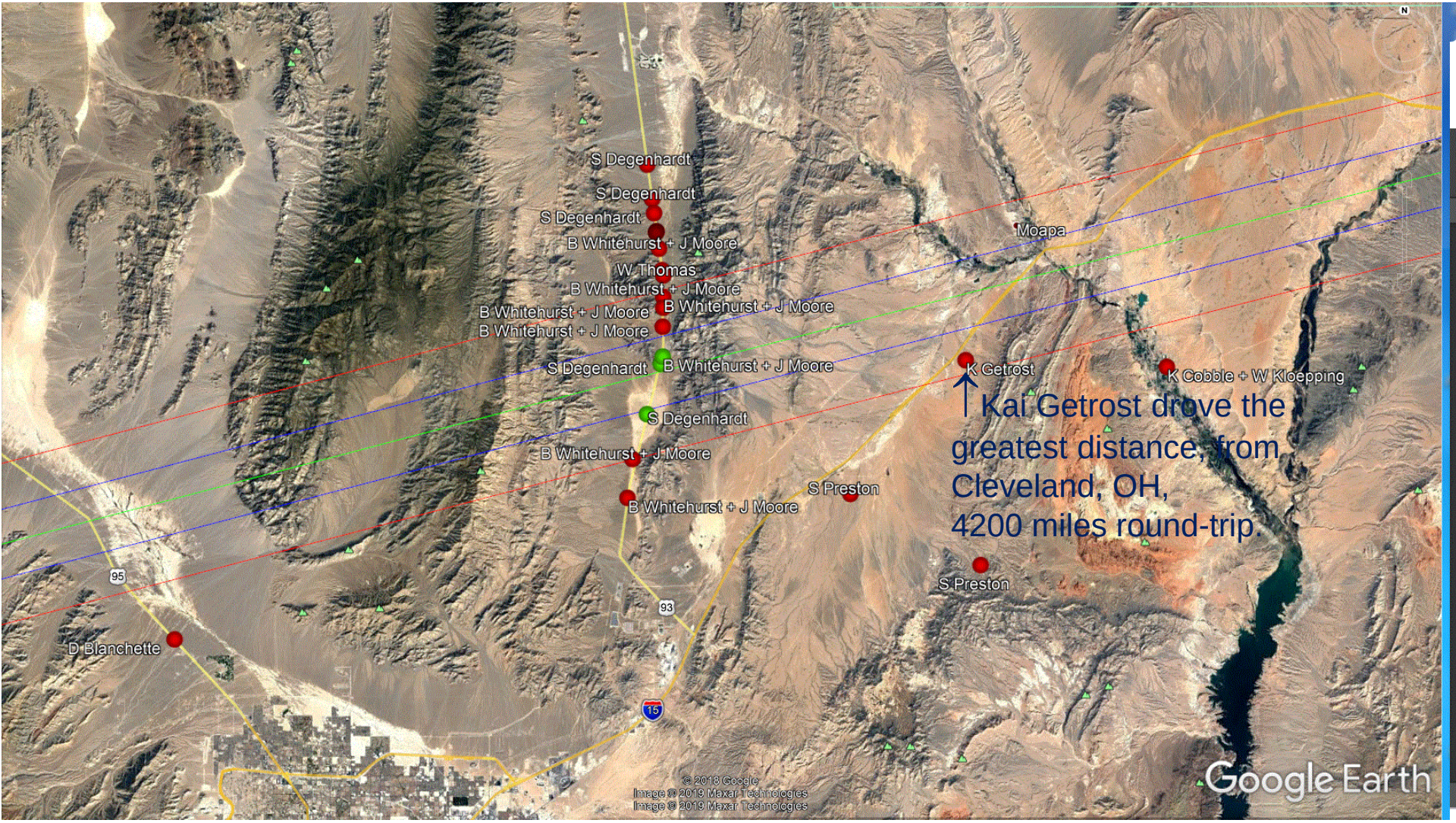
2019 July 29 Phaethon occ'n, s. San Joaquin Valley

Most stations were n. of Las Vegas; others were n. of Ridgecrest and near Pueblo, Colo.



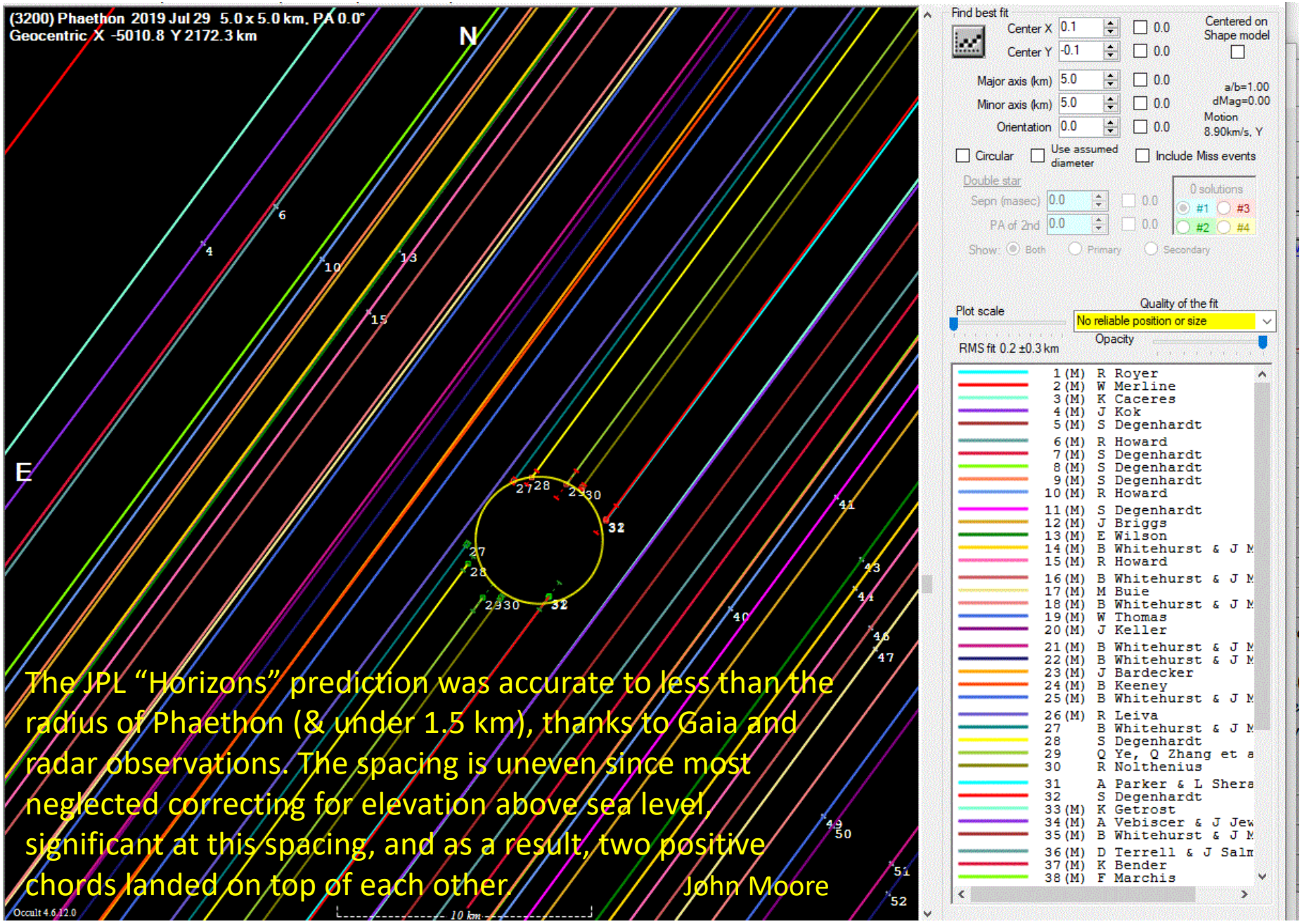
Google Map from SwRI, like those used for their MU69 campaigns. To cover the 3σ zone + many more km to the north and south, to guard against stellar duplicity and other possible unmodelled errors, this pattern of 66 lines, with spacing 680m, was chosen, numbered from s. to n., A01 to A66. Observers were asked to select sites within 100m of their line. All 66 lines were assigned to the many mobile observers who volunteered, plus 4 more between or outside this range. About 9 lines couldn't be filled for various reasons, and another 10 failed to get data. David & Joan Dunham ran 11 stations in the oil fields, 7 of which recorded the star with no occultation.

2019 July 29 Phaethon occ'n, n. of Las Vegas.



Green dots are for stations that recorded the occultation; red dots are for those with misses. Multi-station rundown: J. Moore/S. Whitehurst: 9, all good; D.&J. Dunham: 11, 7 worked, 3 pre-pointed night before on pavers; S. Degenhardt, 6, all good; S. Preston, 5, 2 worked; R. Howard, 3, all good; J. Bardecker, 2, 1 worked (failed remote site trampled by deer, in the actual path).

2019 July 29 Phaethon occ'n, all successful chords

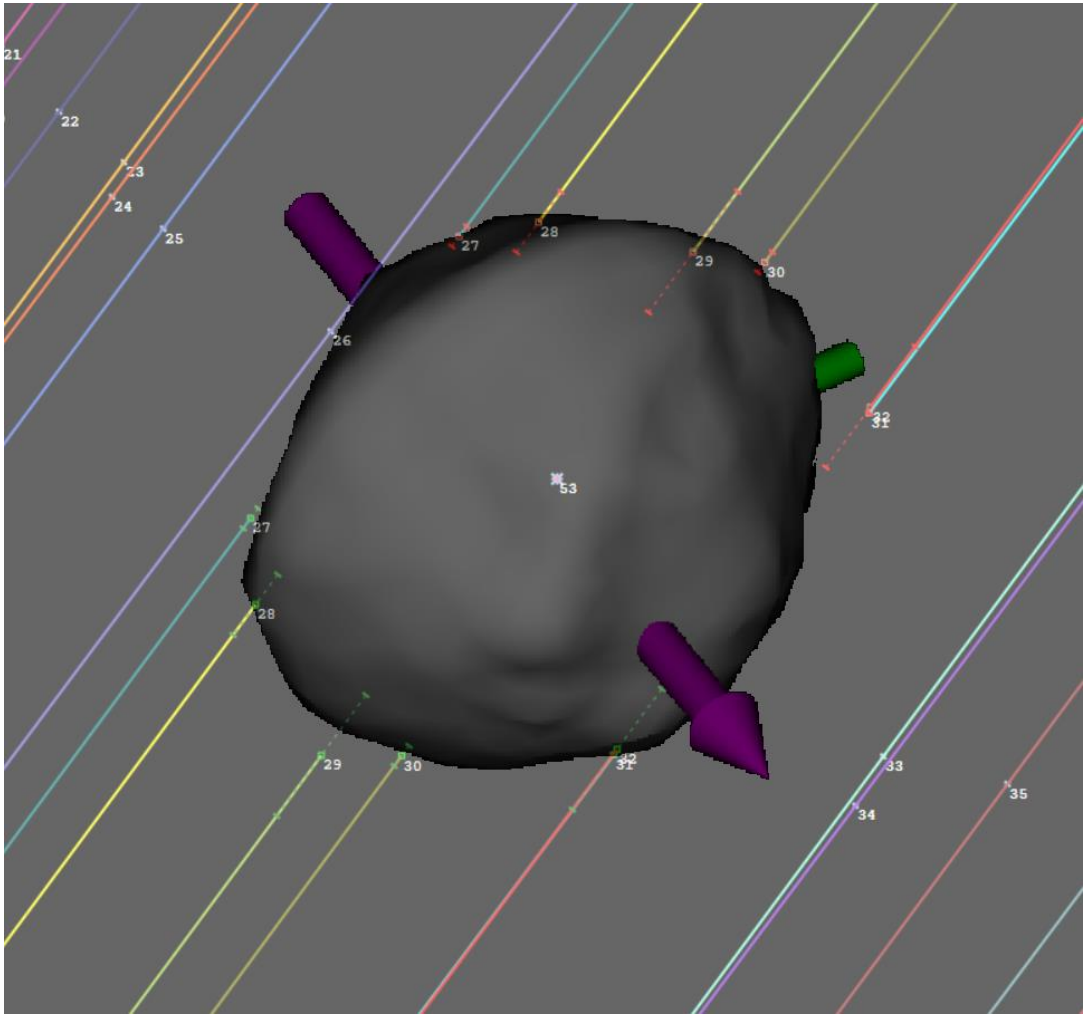


The JPL "Horizons" prediction was accurate to less than the radius of Phaethon (& under 1.5 km), thanks to Gaia and radar observations. The spacing is uneven since most neglected correcting for elevation above sea level, significant at this spacing, and as a result, two positive chords landed on top of each other.

John Moore

2019 July 29 Phaethon occultation, positive chords

fitted to a shape model determined from 2017 December Arecibo radar observations

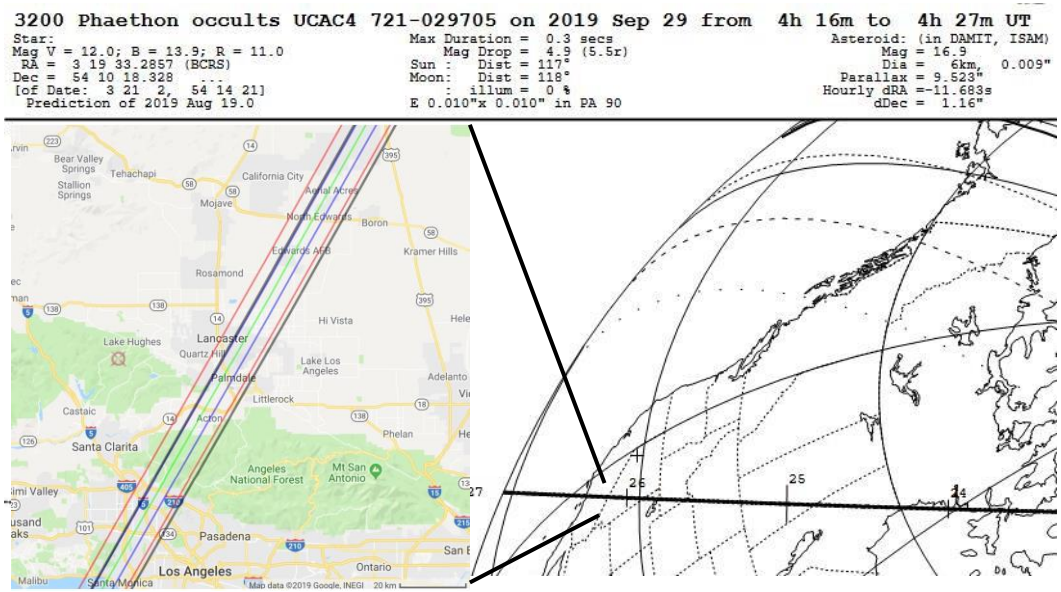


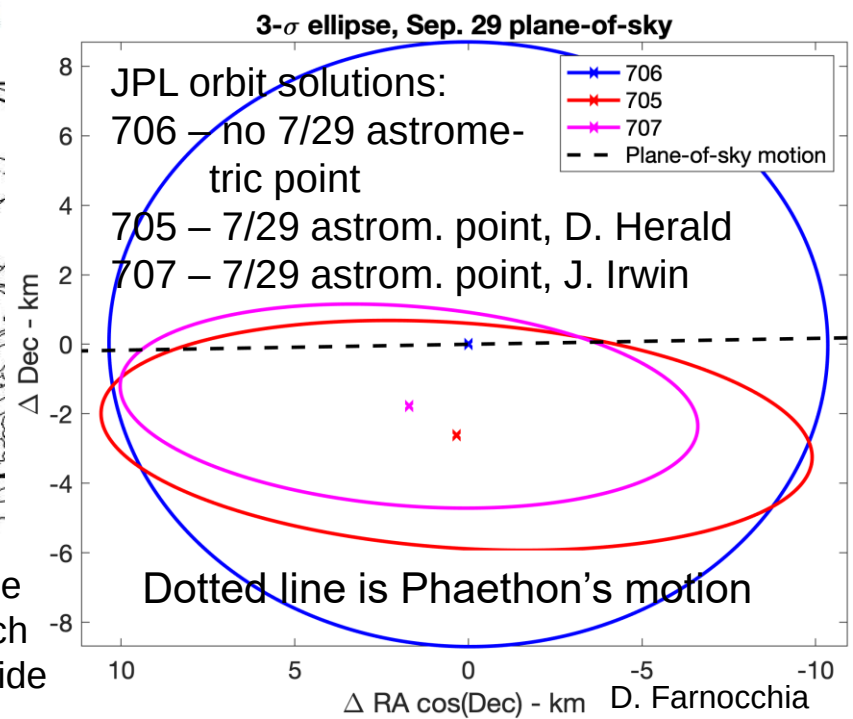
by
Dave Herald and
Sean Marshall

The event provided accurate information about Phaethon's size (confirming the radar value), shape, and orbit that will be valuable for DESTINY+'s planning, and will help obtain more data from future occultations that can be better predicted.

THE 2019 SEPT. 29 OCC'N BY PHAETHON IN CALIFORNIA

- Occultations on Aug. 21 (Japan, found by H. Noda), Sept. 13 (n. Europe), and 14 (s.e. USA) were clouded out. I. Sato predicted the Sept. 13 and 14 events, and one on Oct. 16 in Japan that was also clouded out.
- On Sept. 29th, the target star, UCAC4 721-029705, was mag. 12.0, so only 4 observers tried it. D & J Dunham ran 6 stations, 3 on paver stones. Clouds prevented observation south of the Mojave Desert.
- For locating stations, we used IOTA's interactive Google map by Derek Breit; it allows plotting 2 lines at user-specified offset distances from center.
- An Excel file gave offset distances that allowed plotting paths corrected for height above sea level.
- 17 bands 635m wide were defined that covered the expected zone; we planned to occupy 9 alternating bands, A01 to A09 from northwest to southeast.
- J. Bardecker planned to try it, but wintery weather at his home prevented travel; we cancelled A08.

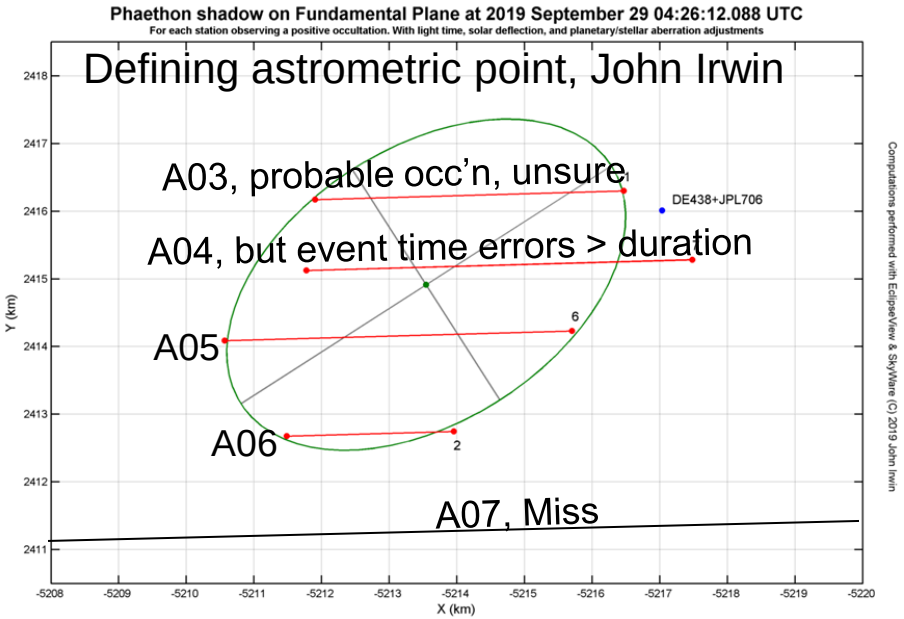


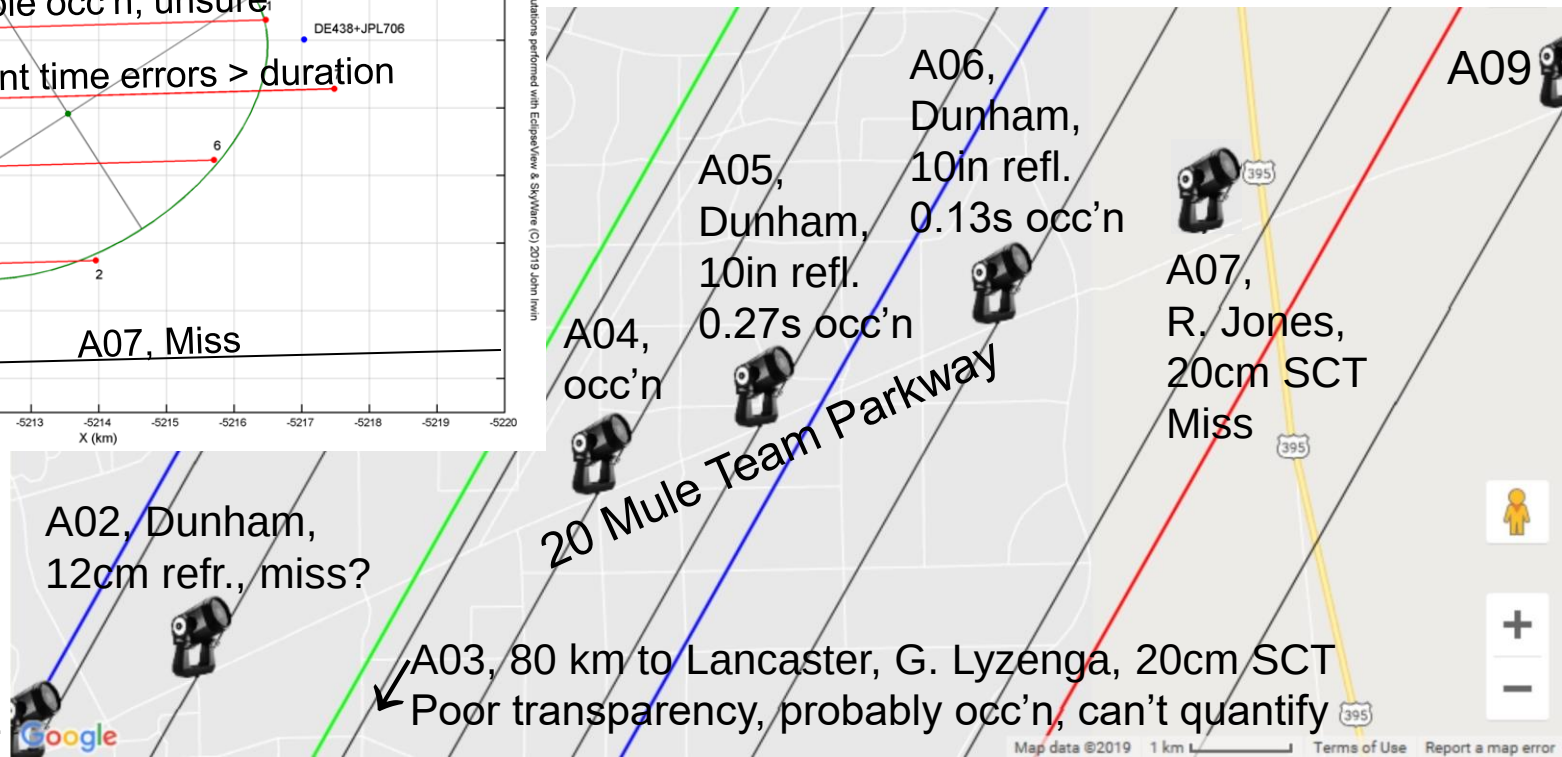


2σ limits encompassing both JPL 705 & 707, from the baseline 706 prediction, +Phaethon radius were from +2.0 to -6.2, which projected to +3.0 to -7.8 km on the ground, 17 bands 635m wide

D. Farnocchia

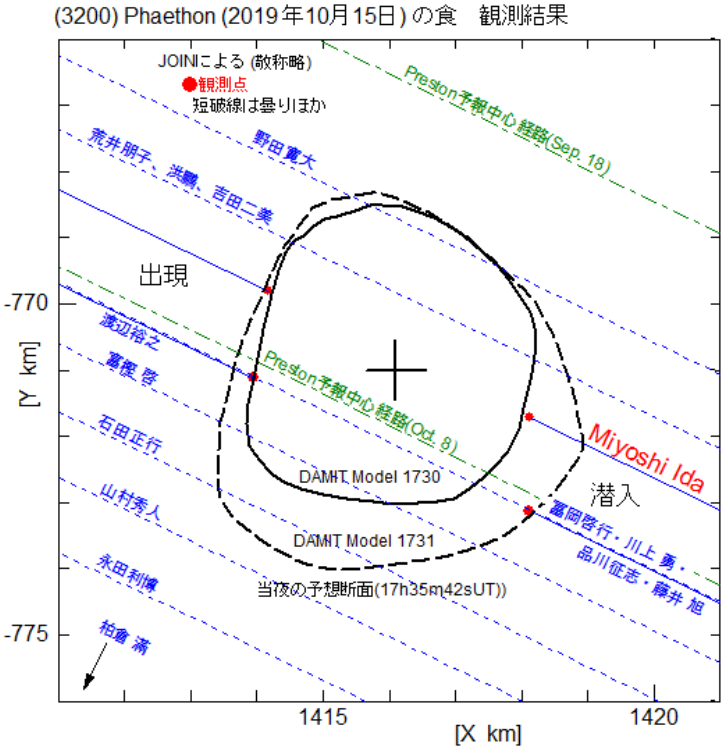
- There was less than 3 hours of usable dark time before the event, so D and J Dunham set up stations A01, A04, and A09 on paver stones the night before, with 12cm telescopes that would be marginal for this event.
- On event night, they set up and pre-pointed 10-in. (25cm) suitcase telescopes (as shown below left) at remote stations A05 and A06, and then set up A02 with a 12cm refractor, their attended site. Significant wind, but no shaking at event time for all critical sites.
- The observations were too poor to improve the size and shape of Phaethon but allowed defining a second accurate astrometric point that would allow better predictions of the October occultations.
- That was accomplished with JPL 711, which used J. Irwin's Sept. 29th astrometric point, along with the one from July 29th. This further shrunk the error ellipses, especially the width (time direction). The Sept. 29th astrometric point matched JPL solution 707 well.

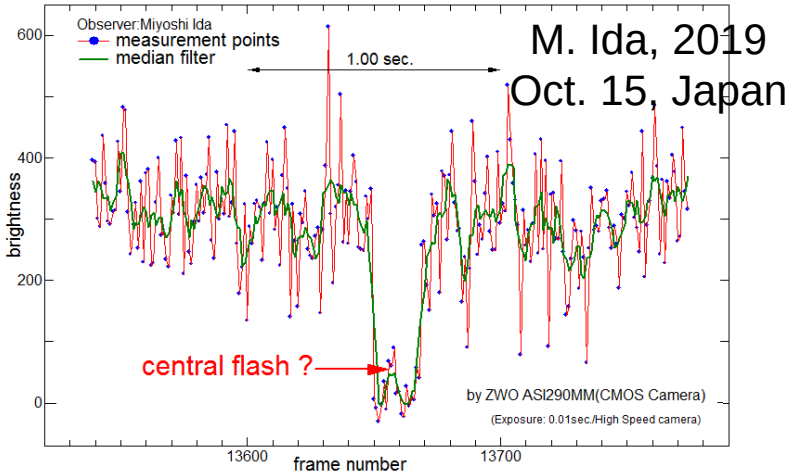




PHAETHON OCCULTATIONS DURING 2019 OCTOBER

- JPL solution 711, issued on Oct. 8, used astrometric points from both the July 29th and Sept. 29th occultations that proved to be so accurate that it needed no further updating, to successfully predict 4 occultations during Oct. 2019 that were each observed from 2 or 3 stations. **I learned later that the JPL Horizons team was pleased that the solution allowed a determination of Phaethon's non-gravitational parameter to 9-sigma accuracy, while before the July event, it was known to only about 2-sigma.** In Oct., apparently, none of the target stars were double. The observed events are described below.
- Oct. 12, 11.3-mag. TYC 3293-01959-1: 9 bands were defined, similar to those for the Sept. 29th occultation, but observers in Texas who were going to occupy most bands cancelled due to heavy cloud cover and rain. The event was observed by two mobile teams in the far western suburbs of Richmond, VA. The observers were from the Univ. of Virginia in Charlottesville; both teams used 14-in. Hyperstar SCT's with QHY 174 GPS cameras. The A03 team was led by Matt Nelson while the A05 team was led by Michael Skrutskie.
- Oct. 15, 11.5-mag. TYC 3292-00570-1: Ten stations were deployed in Japan across the predicted path at 1-km intervals. The occultation was recorded at two stations, by Miyoshi Ida using a 20cm SCT with an ASI290MM camera (exposures 0.01s), and at the other, by Hiroyuki Tomioka et al.; they used a 25cm f/5 BRC and WAT-120N video camera and an IOTA-VTI. M. Ida may have had a "central flash", perhaps the star appearing faintly in a deep valley of Phaethon. Another station much farther south had no occultation. The other stations, including several near the chords of the successful stations, failed due mainly to clouds and fog. See the top of the next slide for a preliminary reduction profile (dashed lines are for the stations that were set up, but could not observe due to clouds or fog) and for M. Ida's light curve.

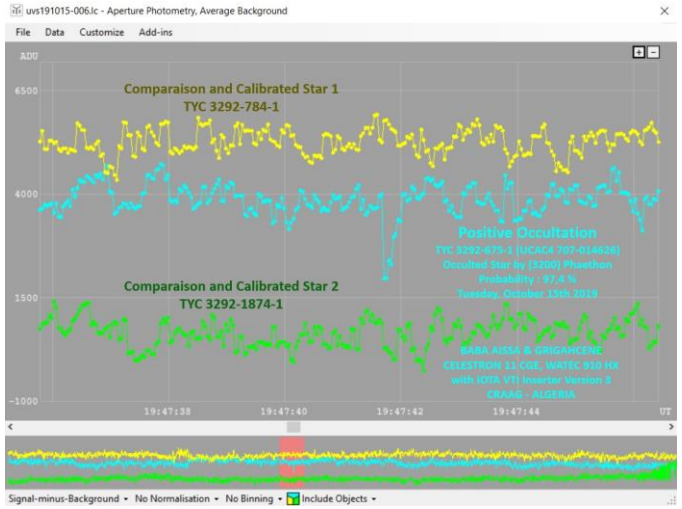


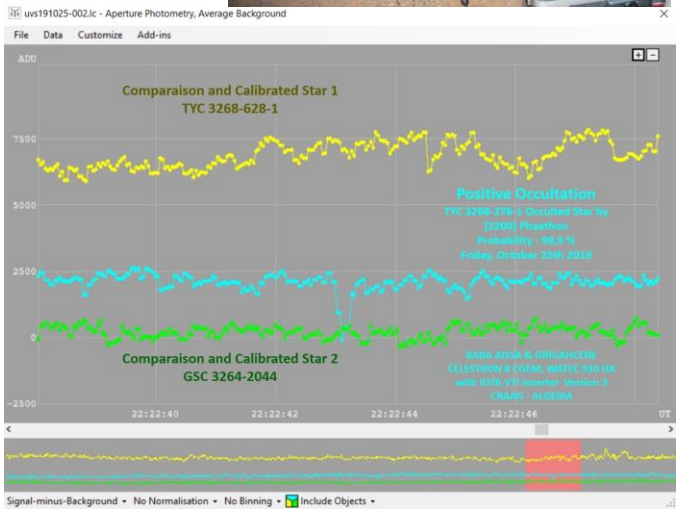


- Oct. 15, 11.1-mag. UCAC4 707-014626: The occultation was observed from two mobile stations in Europe and one in Algeria:
  - Paolo Tanga led a team, including the other co-authors from Observatoire de la Côte d'Azur, to a site in s. France 700m from the predicted central line. They used a portable 1-meter telescope (right) with a QHY 174 GPS camera that recorded 120 frames per second; they had some dropped frames, but none during the event, which a preliminary analysis shows lasted 0.22 second.
  - Christian Weber used a portable 25cm Newtonian reflector to record the occultation with a QHY 174GPS camera with 0.04s exposures. There were some thin clouds, but the 0.22s occultation was clear. He was near Velten, Germany.
  - Djounai Baba Aissa used a portable 20cm SCT with IOTA-VTI to record the occultation from Djendel (Ain Defla), Algeria.

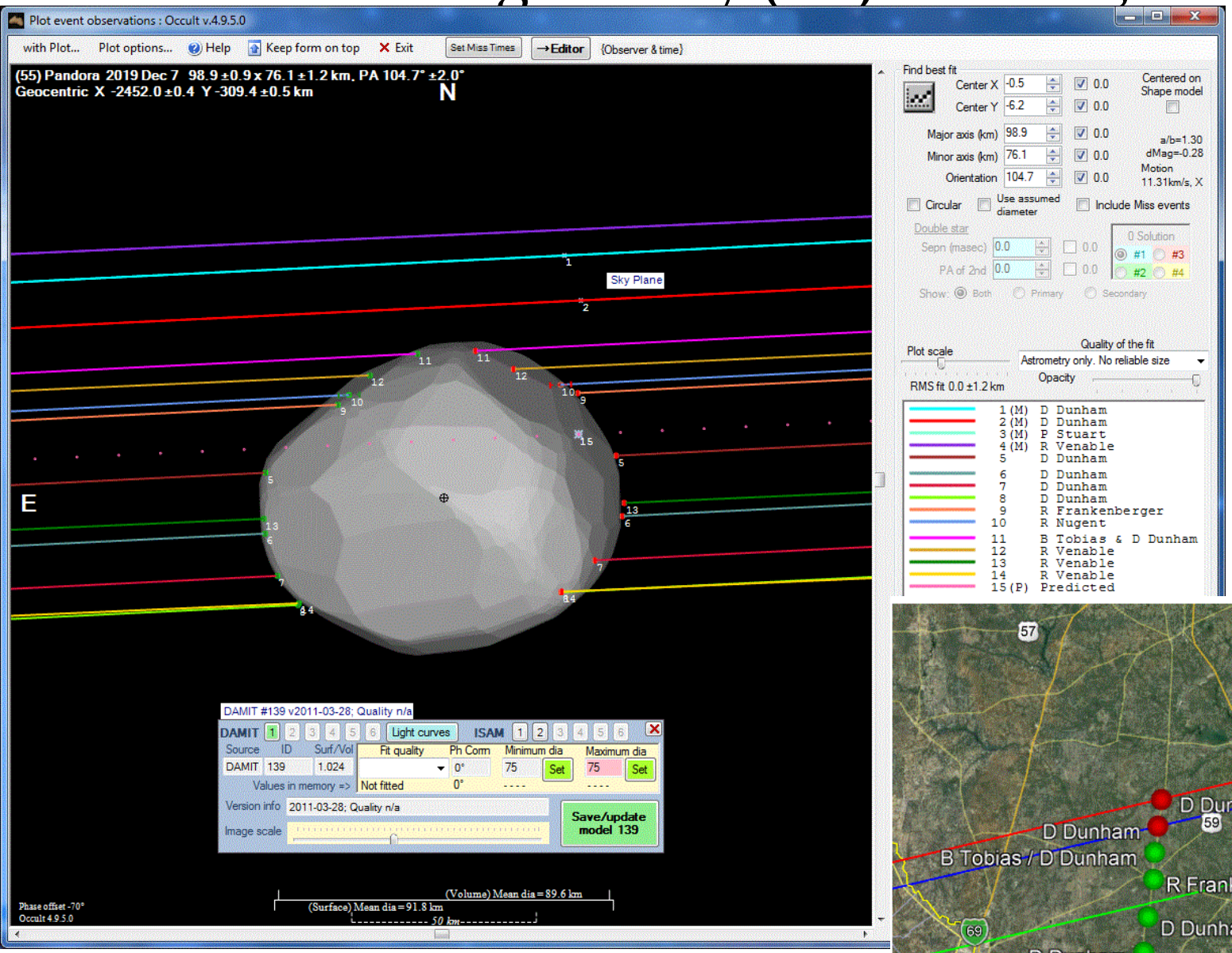
- Oct. 25, 11.3-mag. TYC 3268-00276-1: The occultation was observed from Italy by two observers using the CCD drift scan technique described at (http://www.asteroidoccultation.com/observations/DriftScan/Index.htm) with NTP timing with their recording computers. The observers were Sauro Donati with a 30cm telescope, and a team, M. Bachini, G Succi, F. Mancini, E. DaL Canto, and A. Buti with a 20cm telescope.
  The occultation was also recorded by Djounai Baba Aissa using a portable 20cm SCT with IOTA-VTI from Nedroma (Tlemcen), Algeria. With this event, Djounai became the first person to record TWO occultations by Phaethon since he also observed the 2nd occultation of Oct. 15. He travelled to locations close to the predicted central line for both events.

2 Phaethon occ'ns observed in 10 days in Algeria, by Djounai Baba Aissa and Z. Grigahcene, Algiers Observatory - CRAAG

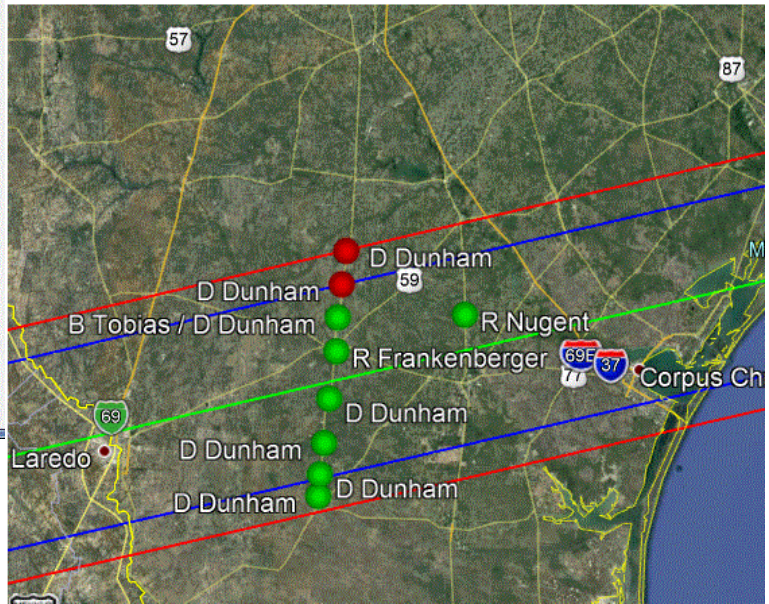




Occ'n of 6.5-mag. star by (55) Pandora, 2019 Dec. 7



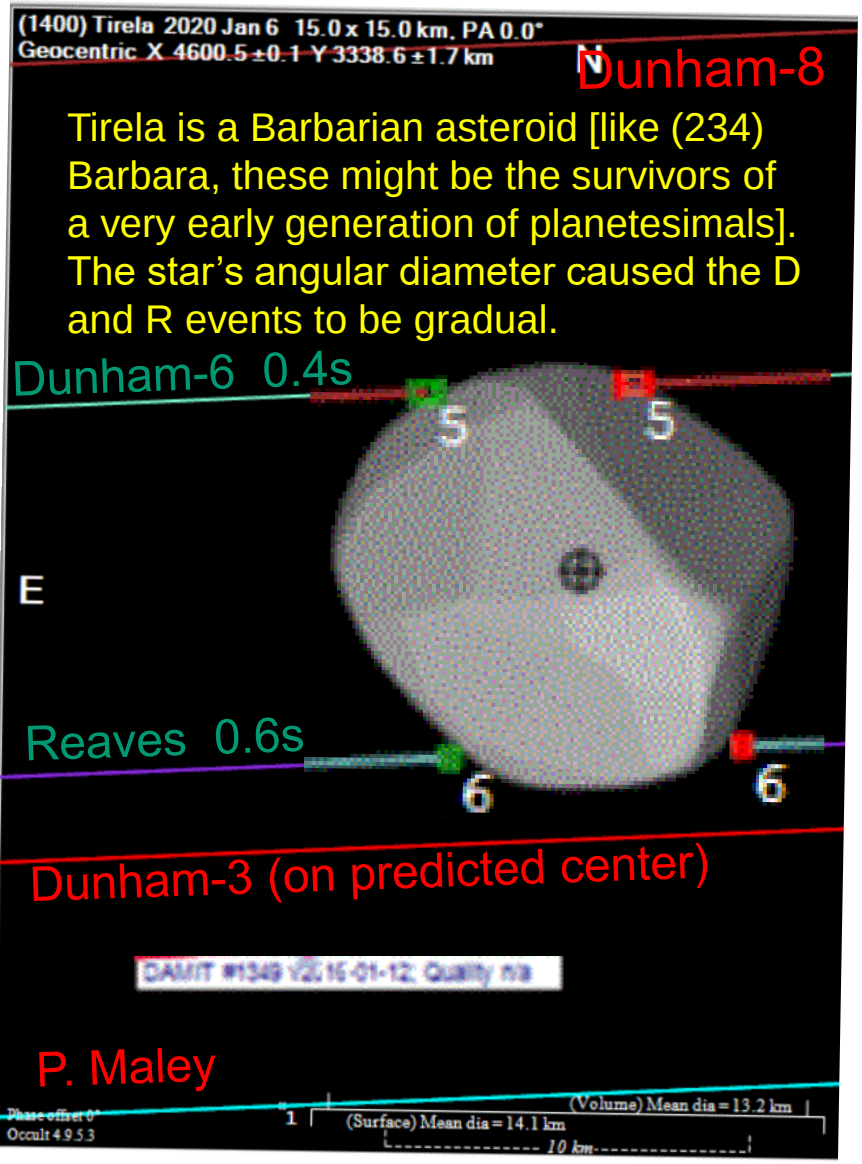
Map below shows stations in s.-cen. Texas. Green line, pred. center; blue lines, pred. limits, & red, 1-σ limits. Red dots – misses. Green dots, pos. Stations. The prediction was the final JPL path with Pandora Gaia data It was almost the same as Preston's



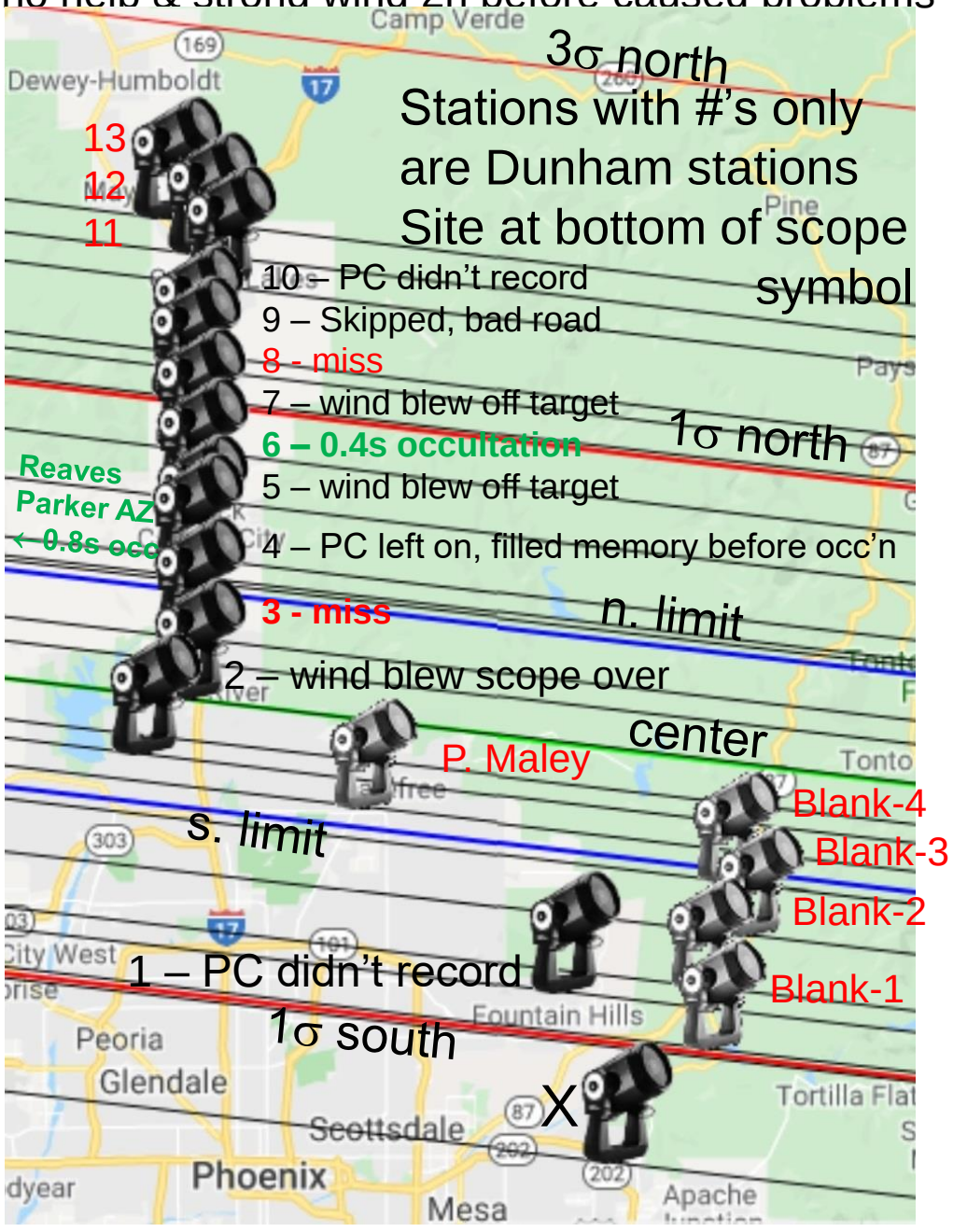
prediction but with smaller errors. The 1st JPL prediction, without Gaia, was a path-width farther south. Actual path was about 1.2σ south. R. Venable added 4 stat'ns in FL.

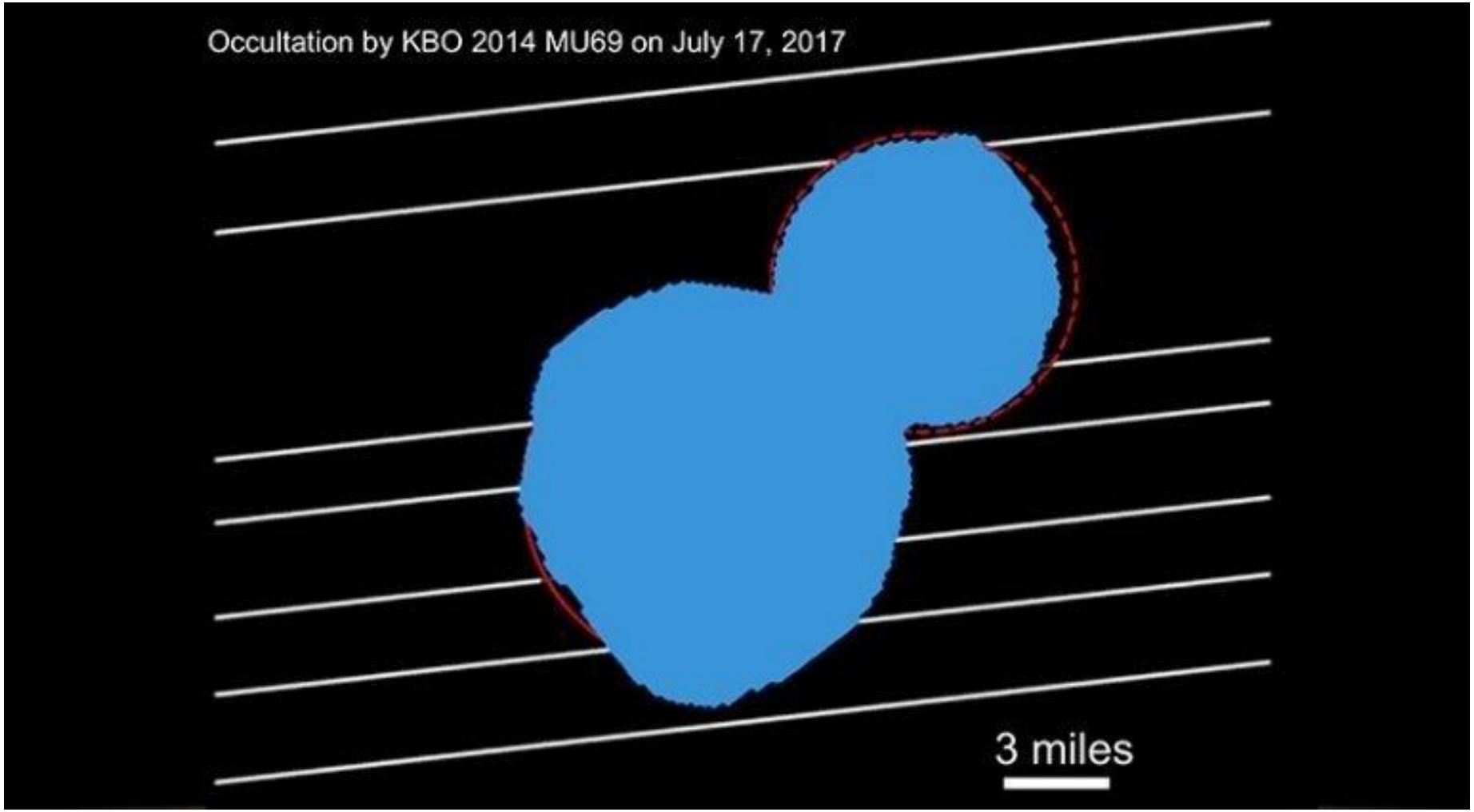
Occ'n of 5.5-mag. star by (1400) Tirela, 2020 Jan. 6

Many failures; 3am Mon. am → we had no help & strong wind 2h before caused problems



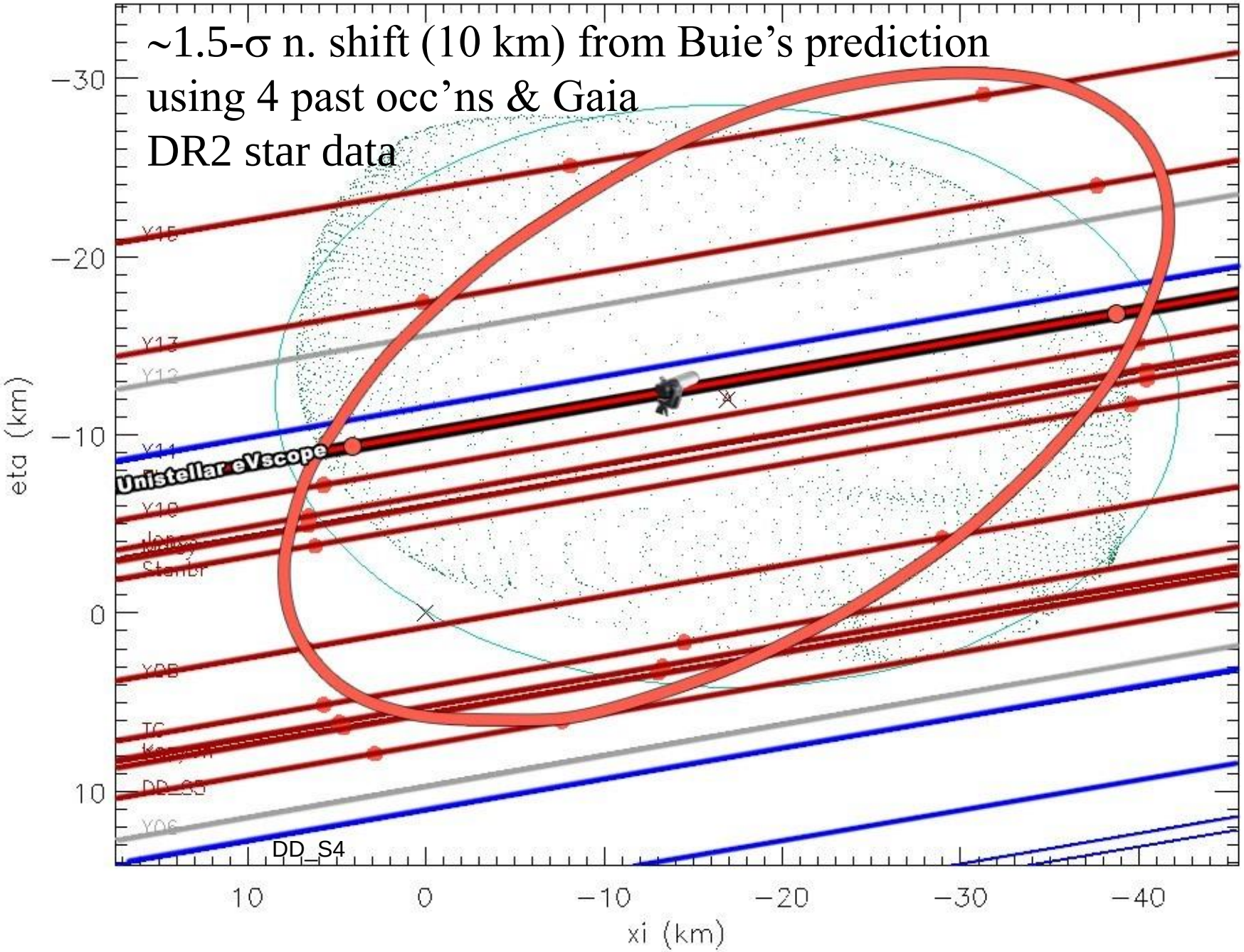
Path shifted 0.7σ north or 0.6 path-width; path ~0.7 of expected width





Marc Buie predicted this occultation by Arrokoth to about 1mas accuracy using HST observations relative to Gaia pre-release DR2 data for the target and reference stars. Paper about these efforts, Buie et al., AJ, 2020, available at https://arxiv.org/abs/2001.00125

(11351) Leucus occultation LE20191229 2019 Dec. 29, Arizona

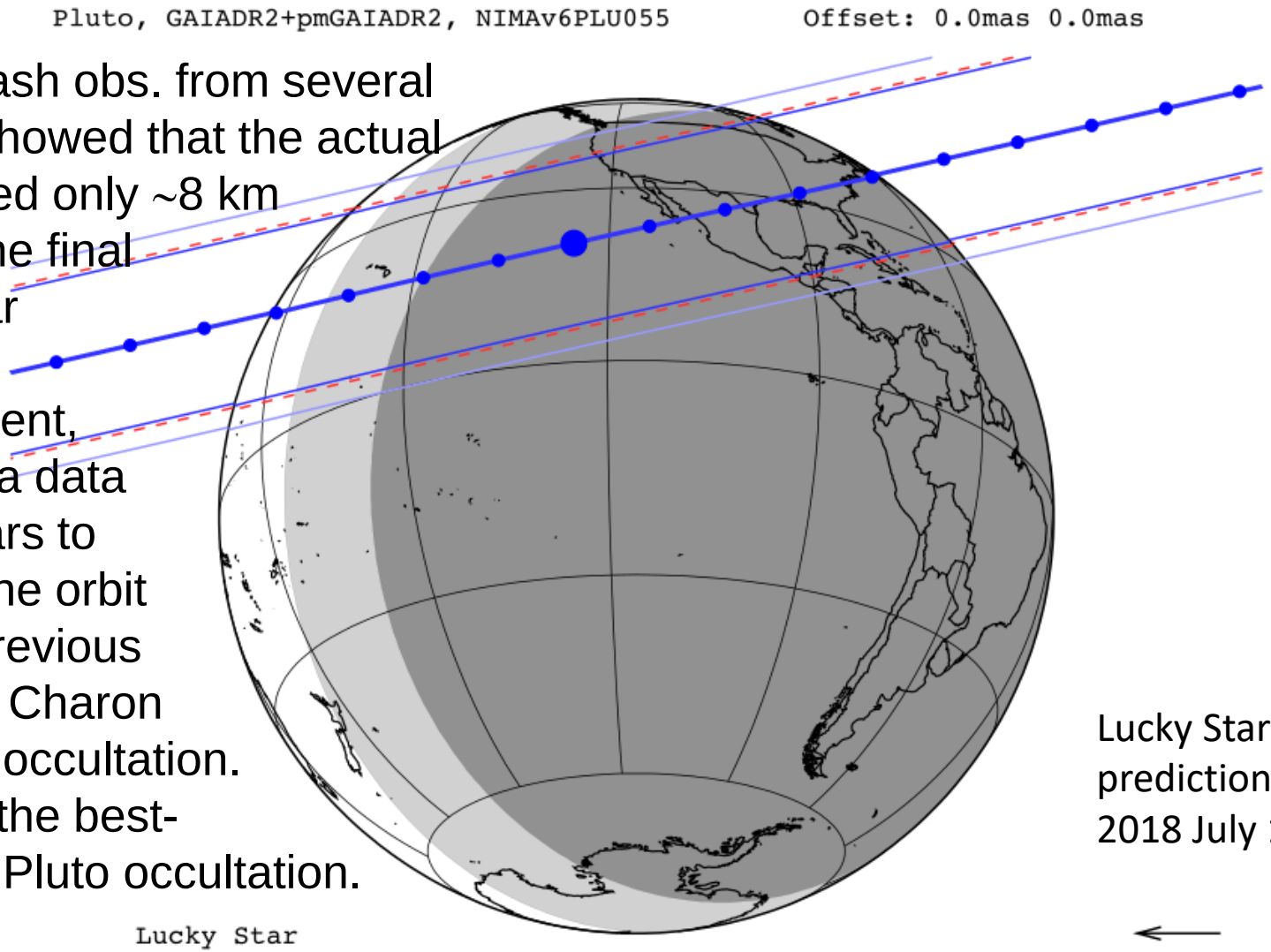


Occultation of 12.9-mag. star by Pluto, 2018 Aug. 15

http://lesia.obspm.fr/lucky-star/predictions/special/pluto20180815.html

Major IOTA campaign for this, the most valuable 2018 N. American occultation

Central flash obs. from several stations showed that the actual path shifted only ~8 km north of the final Lucky Star prediction for this event, using Gaia data for the stars to improve the orbit from all previous Pluto and Charon observed occultation. This was the best-observed Pluto occultation.



Lucky Star prediction of 2018 July 13

yyyy mm dd hh:mm:ss.s	RA_star_J2000	DE_star_J2000	C/A	P/A	vel	Delta	G*	RP*
2018-08-15 05:33:09.7	19 22 10.4687	-21 58 49.020	0.180	347.11	-19.33	32.7670	13.0	12.5

List of astrometric positions from asteroidal occultations by D. Herald

Dave Herald has been supplying astrometric positions from occultations to the MPC for many years, but the MPC doesn't report positional errors in their system. So the full value of the observations is greatly diluted. JPL uses a standard 0.2" for their errors (the occultation source is identified by MPC) and Steve Preston does something similar. The occultation positions with their tiny errors, as given in this list from Dave Herald (for all events, but for only 2 asteroids shown here) should dominate the solutions, but until these recent efforts, didn't.

Astrometric positions of asteroids derived from occultations - All offsets corrected for the effects of differential pre
Star position has had proper motion, foreshortening and parallax applied, but no deflection

LEFT

Object #	Asteroid	Date Year	m	d	Time h	m	s	OBJECT Right Ascens. h	m	s	Declination o	'	"	STAR Right Ascens. h	m	s	Declination o	'	"	Src Cat	N
303	Josephina	2001	2	7	3	14	14.55	7	56	57.69490	27	23	42.8832	7	56	57.79308	+27	23	41.5056	GDR2	1
303	Josephina	2005	11	18	8	28	54.13	4	58	23.94288	32	51	53.2985	4	58	23.96323	+32	51	53.2080	GDR2	3
303	Josephina	2007	2	22	10	04	19.75	10	45	48.60315	9	05	51.4328	10	45	48.40938	+ 9	5	49.3956	GDR2	1
303	Josephina	2014	9	26	10	56	46.18	17	22	8.28098	-29	17	37.1771	17	22	8.11937	-29	17	36.8753	GDR2	1
303	Josephina	2018	2	10	8	02	01.62	10	38	16.43533	10	47	33.9830	10	38	16.48808	+10	47	32.4265	GDR2	7
530	Turandot	2006	2	24	7	29	40.83	8	20	0.21713	19	51	04.8357	8	20	0.08998	+19	51	3.4340	GDR2	8
530	Turandot	2006	5	23	21	08	30.20	8	39	59.15541	20	01	54.2000	8	39	59.05759	+20	1	53.0181	GDR2	1
530	Turandot	2014	6	14	7	38	15.33	17	52	5.76262	-14	11	41.6782	17	52	5.81253	-14	11	45.6469	GDR2	1
530	Turandot	2014	7	17	1	23	13.22	17	27	34.97135	-15	40	37.7119	17	27	34.76191	-15	40	41.5272	GDR2	1
530	Turandot	2019	4	1	7	20	18.35	14	20	47.70383	- 1	49	53.4350	14	20	47.79515	- 1	49	55.4478	GDR2	3
530	Turandot	2020	3	4	from N.Z.			http://occultations.org.nz/planet/2020/results/20200304_530_Turandot_TYC_630													

Needs more Work; errors for most 2- & 3-chord Events are too small.

ential precession, nutation, aberration and deflection

| -From the Occultation- |

RIGHT

Src Cat	N	OFFSETS dRA asec	dDec asec	<-- Track PA o	Event T s	UNCERTAINTIES T s	track mas	xtrack mas	dRA mas	dDec mas	corln mas	Star mas	mas	--> FLAGS Dup Src	RU WE	shape cntrd
GDR2	1	-1.3076	+1.3776	87.523	0.20	1.90	13.8	27.6	13.8	27.6	13.8	1.3	1.1	-	-	-
GDR2	3	-0.2565	+0.0906	92.270	0.50	0.00	0.0	0.0	0.0	0.0	0.0	2.0	1.3	-	-	-
GDR2	1	+2.8700	+2.0372	104.092	1.25	0.39	3.3	26.6	7.2	25.8	7.2	0.7	0.7	-	-	-
GDR2	1	+2.1141	-0.3018	84.624	0.08	0.24	2.2	17.7	2.7	17.6	2.7	0.2	0.2	-	-	-
GDR2	7	-0.7772	+1.5565	104.160	0.11	0.05	0.4	0.6	0.4	0.6	0.4	0.2	0.3	-	-	-
GDR2	8	+1.7939	+1.4017	112.342	0.42	0.07	0.4	0.6	0.4	0.6	0.4	1.0	0.8	-	-	-
GDR2	1	+1.3785	+1.1820	101.945	0.50	0.17	1.4	11.2	2.7	11.0	2.7	1.6	1.1	-	x	-
GDR2	1	-0.7259	+3.9687	82.620	0.14	0.41	3.3	26.8	4.7	26.6	4.7	0.1	0.1	-	-	-
GDR2	1	+3.0247	+3.8153	63.981	0.17	0.56	3.3	26.3	11.9	23.7	11.9	1.2	0.9	-	x	-
GDR2	3	-1.3692	+2.0128	121.964	0.67	0.21	1.4	1.6	1.5	1.5	1.5	0.2	0.1	-	-	-

dot_TYC_6300_01069_1_Loader_lc.png (1 chord)

These flags are Important – Dup Src and (high) RUWE, for predictions, too!

Better ways of computing errors for events with only 2 or 3 chords are given in a new paper recently submitted to M.N.R.A.S. by Dave Herald:

MNRAS 000, 1–21 (2020) Preprint 18 August 2020 Compiled using MNRAS LATEX style file v3.0

Precise astrometry and diameters of asteroids from occultations – a data-set of observations and their interpretation

David Herald [1★], David Gault[2], Robert Anderson[3], David Dunham[4], Eric Frappa[5], Tsutomu Hayamizu[6], Steve Kerr[7], Kazuhisa Miyashita[8], John Moore[9], Hristo Pavlov[10], Steve Preston[11], John Talbot[12], Brad Timerson (deceased)[13]

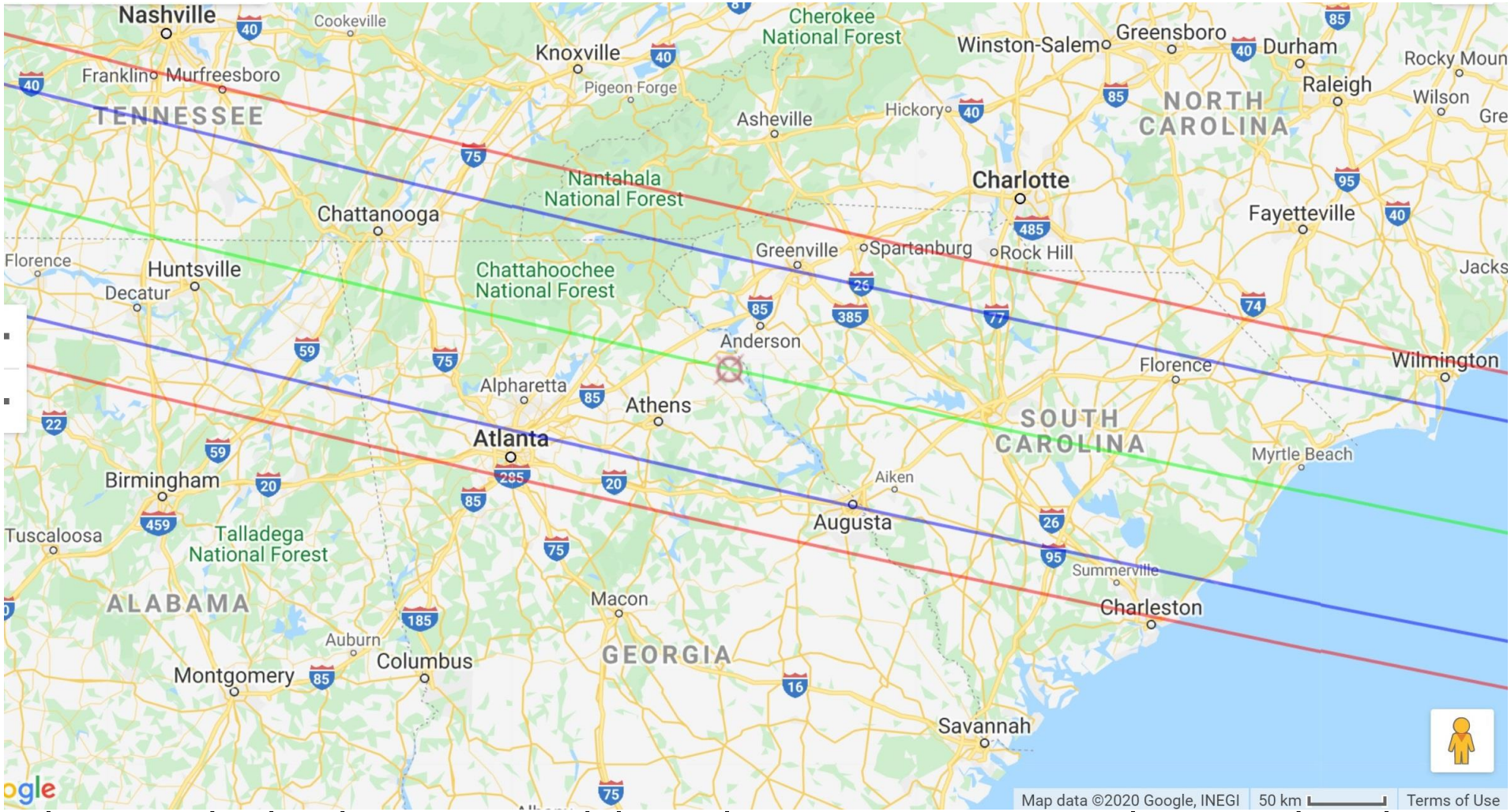
[1]*Trans Tasman Occultation Alliance, drherald@bigpond.net.au*
[2]*Trans Tasman Occultation Alliance, davegault@bigpond.com*
[3]*International Occultation Timing Association, bob.anderson.ok@gmail.com*

ABSTRACT

Occultations of stars by asteroids have been observed since 1961, increasing from a very small number to now over 500 annually. We have created and regularly maintain a growing data-set of more than 5,000 observed asteroidal occultations. The data-set includes: the raw observations; astrometry at the 1 mas level based on centre of mass or figure (not illumination); where possible the asteroid's diameter to 5 km or better, and fits to shape models; the separation and diameters of asteroidal satellites; and double star discoveries with typical separations being in the tens of mas or less. The data-set is published at NASA's Planetary Data System and is regularly updated. We provide here an overview of the data-set, discuss the issues associated with determining the astrometry and diameters, and give examples of what can be derived from the data-set. We also compare the occultation diameters of asteroids with the diameters measured by the satellites *NEOWISE*, *AKARI AcuA*, and *IRAS*, and show that the best satellite-determined diameter is a combination of the diameters from all three satellites.

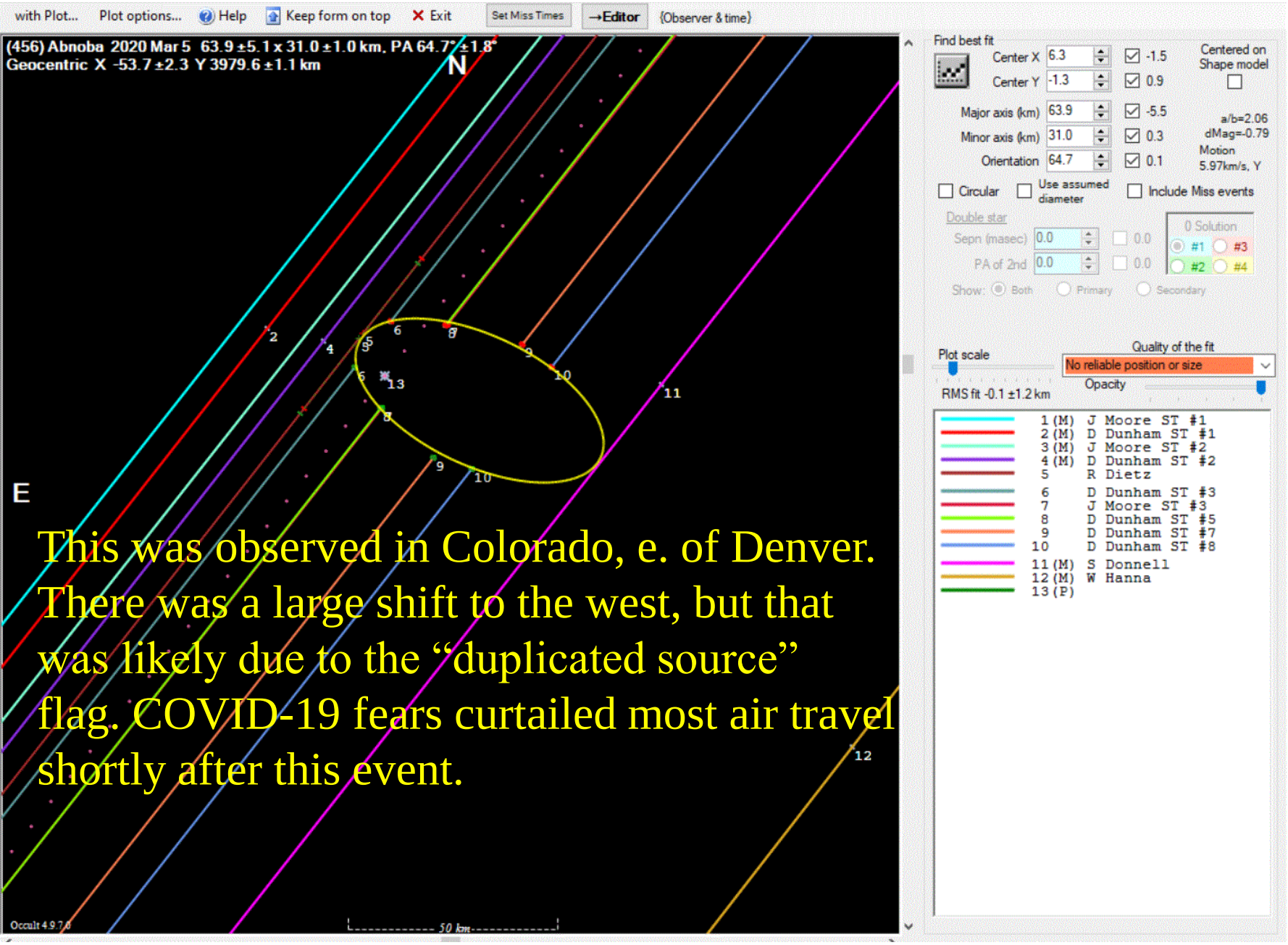
Key words: Asteroids – Occultations – Astronomical data base:Miscellaneous

Occultation of 4.3-mag. nu Ser by (191) Kolga, 2020 Feb. 10



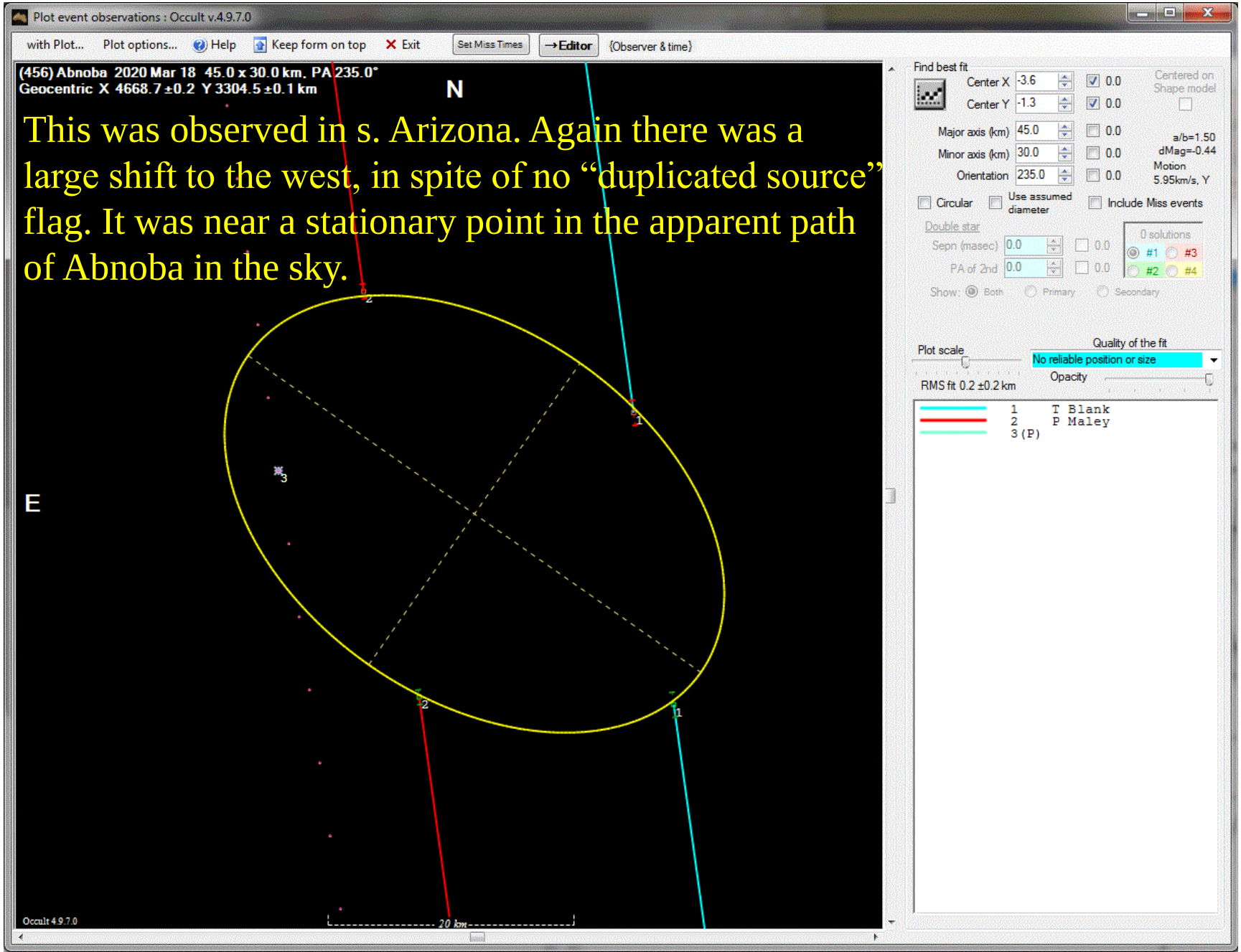
This was the brightest asteroidal occultation in N. America this year, but the weather forecasts were too poor to warrant the effort to travel from either AZ or even s. GA. The IR sat. image showed SC had large breaks in the clouds, but there are no occultation observers currently there. It was totally overcast in the path farther west; it extended to w. Oklahoma where alt. was only 3°.

Occultation of 7.5-mag. star by (456) Abnoba, 2020 Mar. 5



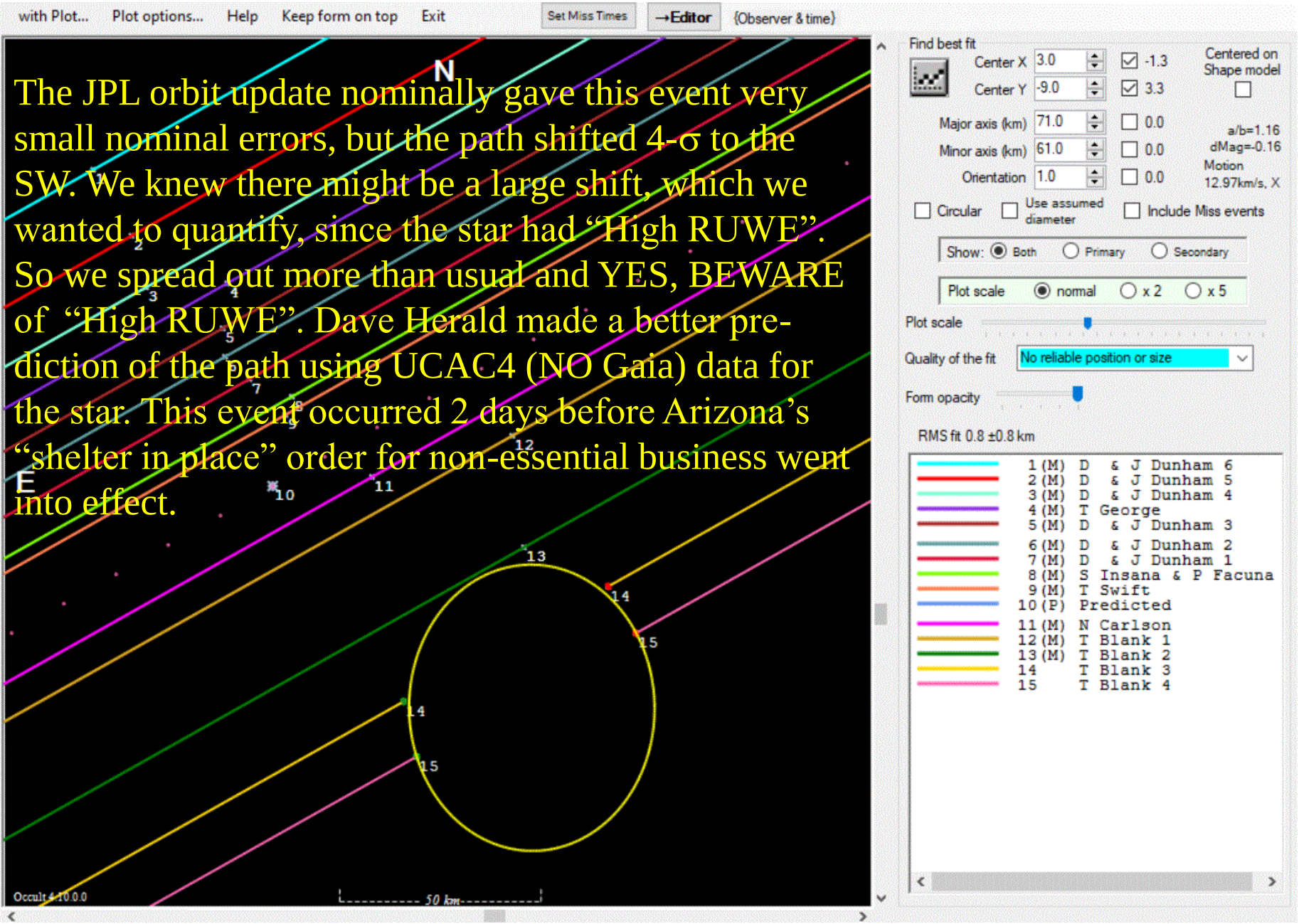
This was observed in Colorado, e. of Denver. There was a large shift to the west, but that was likely due to the "duplicated source" flag. COVID-19 fears curtailed most air travel shortly after this event.

Occultation of 13.3-mag. star by (456) Abnoba, 2020 Mar. 18



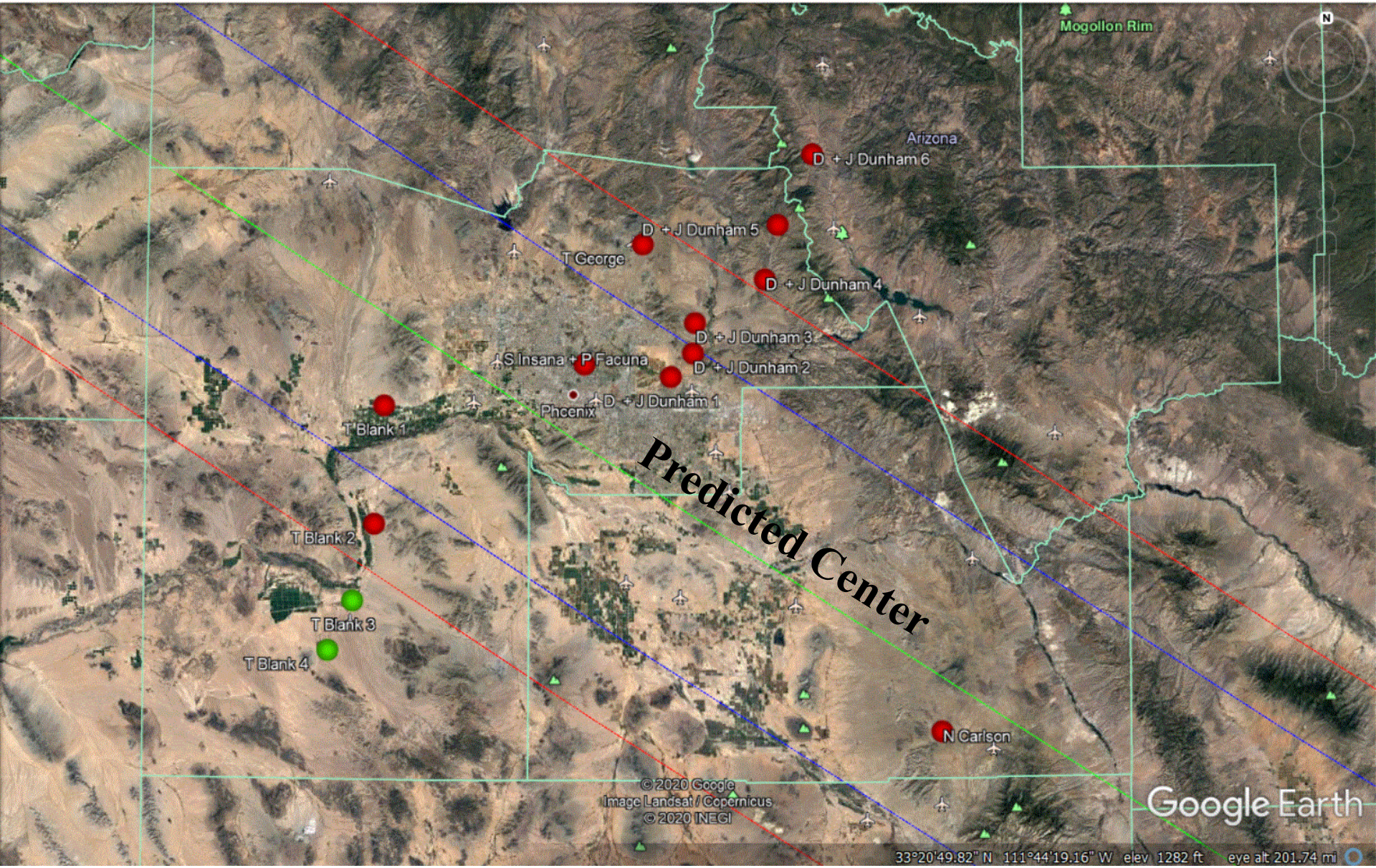
This was observed in s. Arizona. Again there was a large shift to the west, in spite of no "duplicated source" flag. It was near a stationary point in the apparent path of Abnoba in the sky.

Occultation of 10.4-mag. star by (479) Caprera, 2020 Mar. 28

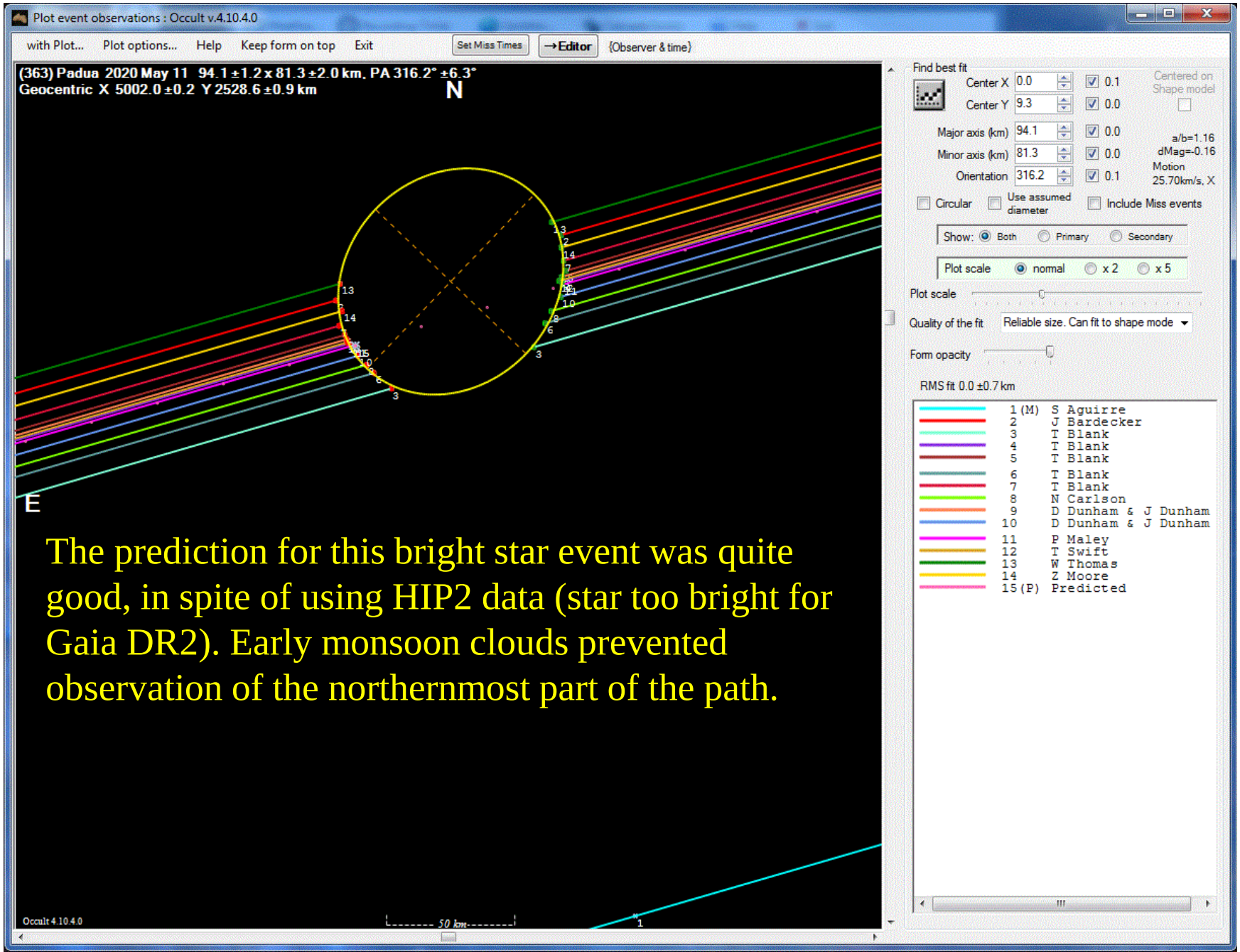


The JPL orbit update nominally gave this event very small nominal errors, but the path shifted 4-σ to the SW. We knew there might be a large shift, which we wanted to quantify, since the star had "High RUWE". So we spread out more than usual and YES, BEWARE of "High RUWE". Dave Herald made a better prediction of the path using UCAC4 (NO Gaia) data for the star. This event occurred 2 days before Arizona's "shelter in place" order for non-essential business went into effect.

Occultation of 10.4-mag. star by (479) Caprera, 2020 Mar. 28

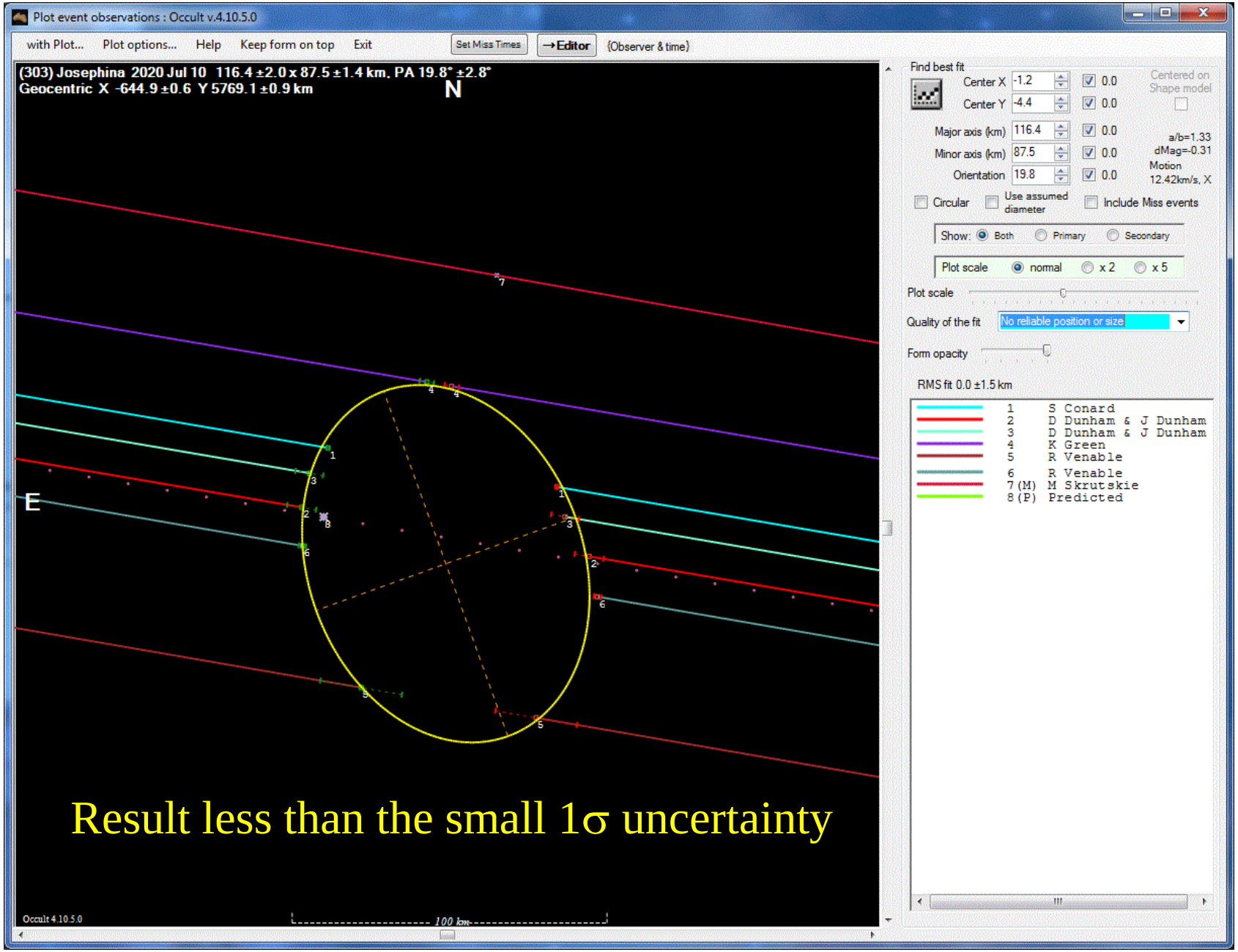


Occultation of 5.5-mag. 14 Cancri by (363) Padua, 2020 May 11



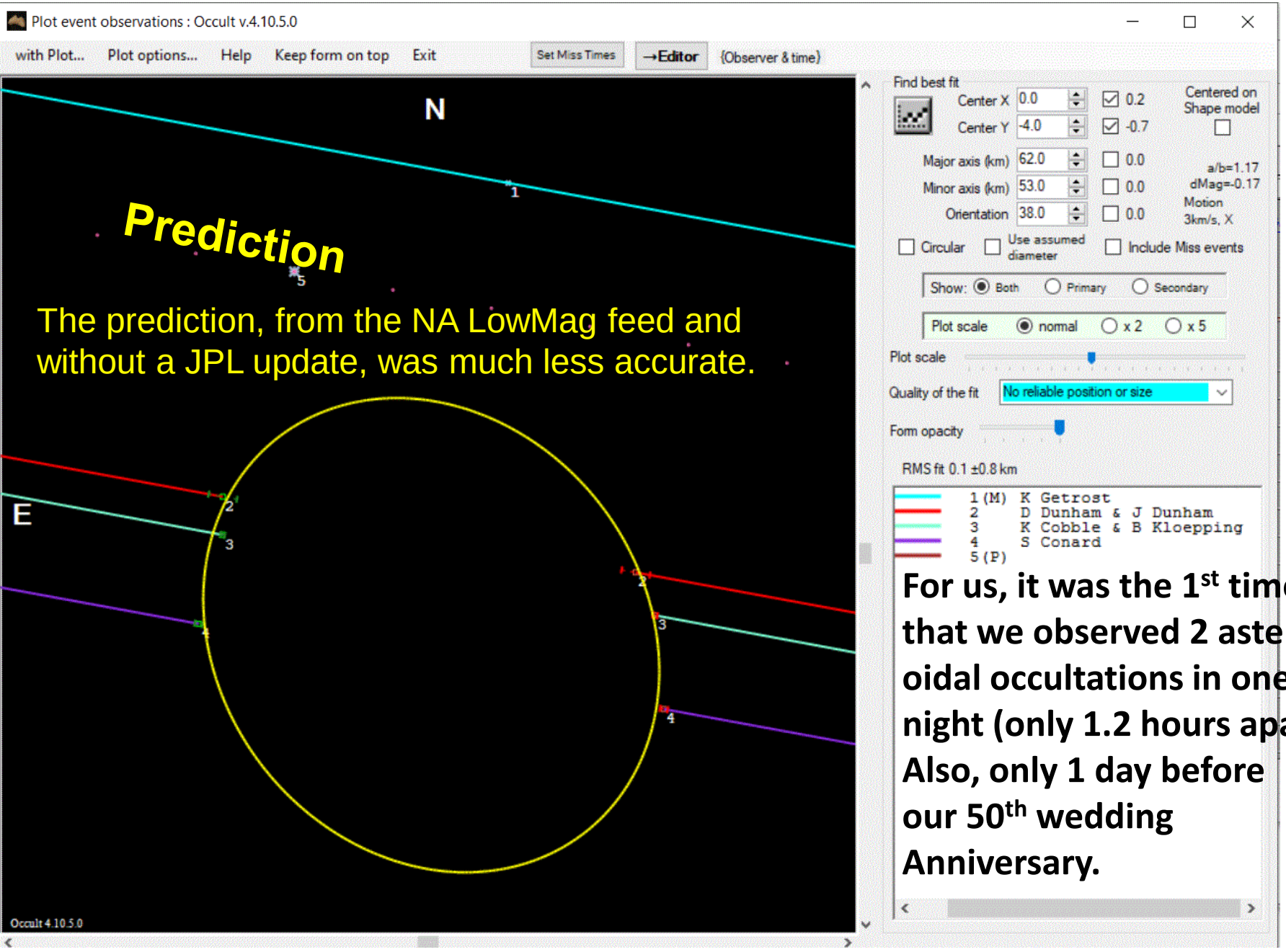
The prediction for this bright star event was quite good, in spite of using HIP2 data (star too bright for Gaia DR2). Early monsoon clouds prevented observation of the northernmost part of the path.

Occultation of 12.6-mag. star by (303) Josephina, 2020 July 10



Result less than the small 1σ uncertainty

Occultation of 12.4-mag. star by (846) Lipperta, 2020 July 10



For us, it was the 1st time that we observed 2 asteroidal occultations in one night (only 1.2 hours apart). Also, only 1 day before our 50th wedding Anniversary.

A Day Later, 50th Wedding Anniversary

1970 July 11, Highland Park, IL. Left to right: Tom Van Flandern, Ron Abileah, Homer DaBoll, Ed Halbach, D Joan Dunham. If not for COVID-19, we would have had a big family reunion at our home, and then would hav been busy with preparations for that rather than for the Josephina occultation.

530 Turandot occults UCAC4 361-199325 on 2020 Jul 27 from 8h 28m to 8h 49m UT

Star:
Mag V = 10.2
RA = 20 32 58.4131 (astrometric)
Dec = -17 51 34.987 ...
[of Date: 20 34 9, -17 47 18]
Prediction of 2020 Apr 6.0

Max Duration = 9.0 secs
Mag Drop = 2.2 (0.0r)
Sun : Dist = 178°
Moon: Dist = 94°
: illum = 48 %
E 0.038"x 0.015" in PA 84

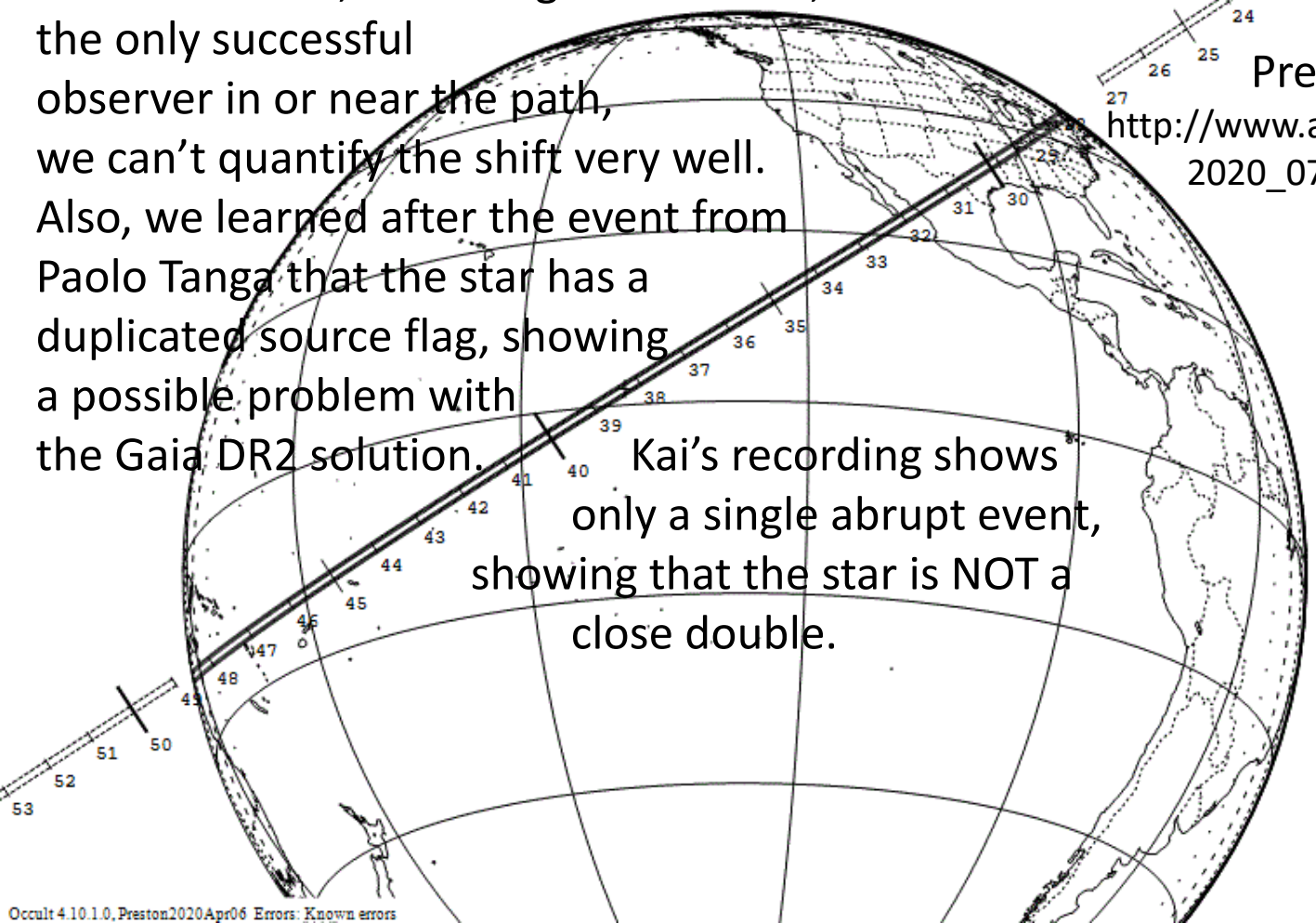
Asteroid:
Mag = 12.3
Dia = 85km, 0.078"
Parallax = 5.814"
Hourly dRA =-1.830s
dDec =-16.97"

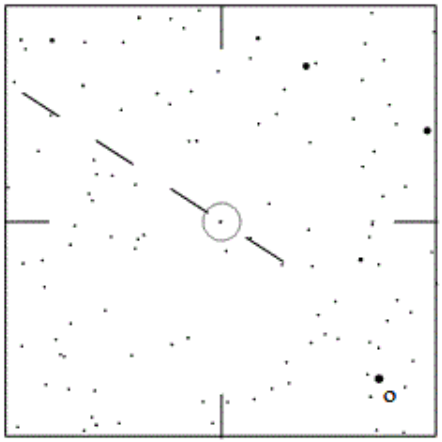
Occultation of 10.2-mag. star by (530) Turandot, 2020 July 27
Updated by JPL; 2nd & brightest of 2 Turandot events this night

Kai Getrost recorded a 9.1s occ'n from Ohio, from about 15 km south of center, indicating a small shift, but since he was the only successful observer in or near the path, we can't quantify the shift very well. Also, we learned after the event from Paolo Tanga that the star has a duplicated source flag, showing a possible problem with the Gaia DR2 solution.

Prediction details at http://www.asteroidoccultation.com/2020_07/0727_530_65596.htm

Kai's recording shows only a single abrupt event, showing that the star is NOT a close double.





Occult 4.10.1.0, Preston2020Apr06 Errors: Known errors

530 Turandot occults TYC 6334-00614-1 on 2020 Jul 27 from 8h 5m to 8h 19m UT

Star:
Mag V = 10.8
RA = 20 32 59.3028 (astrometric)
Dec = -17 51 29.446 ...
[of Date: 20 34 10, -17 47 13]
Prediction of 2020 Jun 26.0

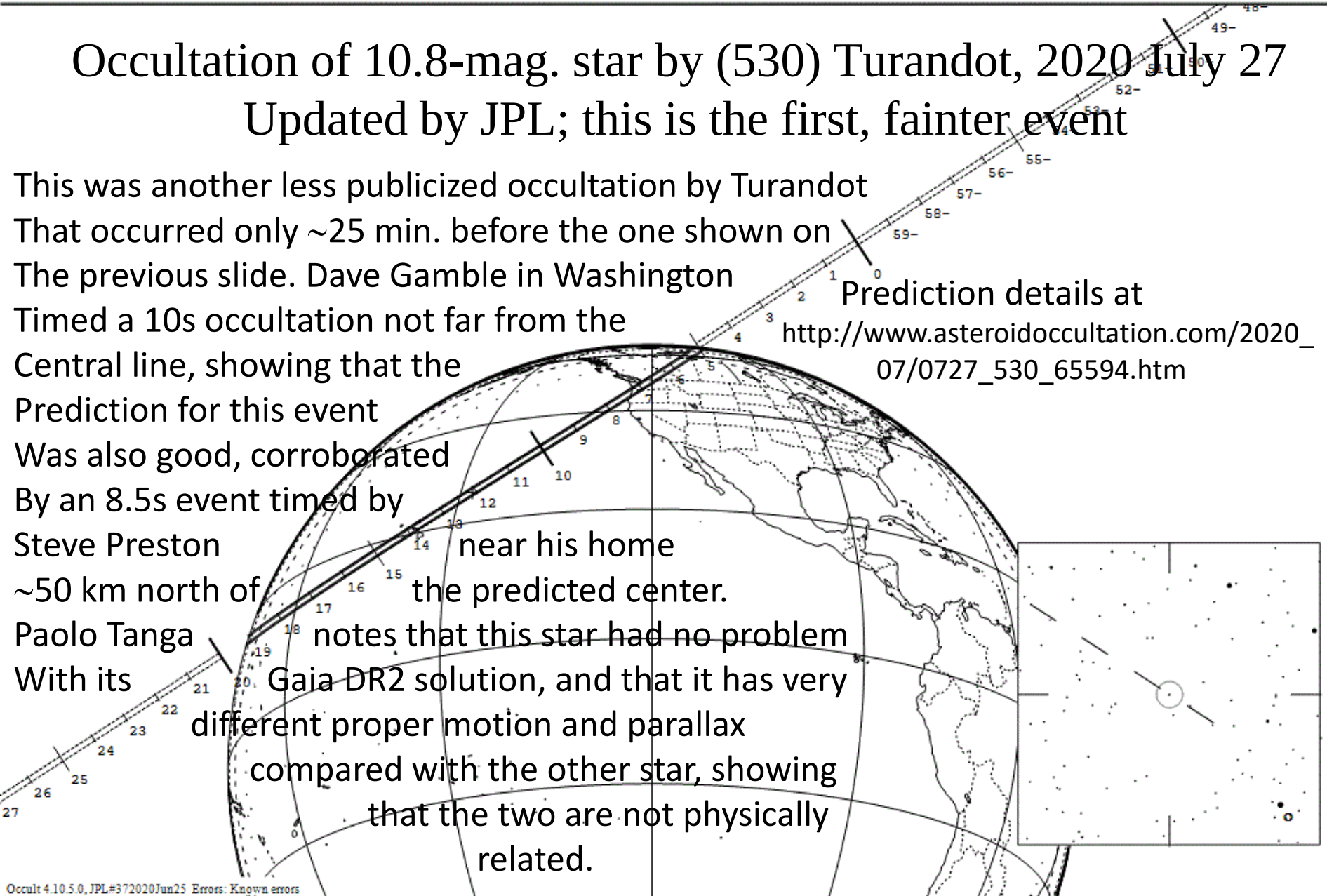
Max Duration = 8.9 secs
Mag Drop = 1.8 (0.0r)
Sun : Dist = 178°
Moon: Dist = 94°
: illum = 48 %
E 0.032"x 0.003" in PA 84

Asteroid:
Mag = 12.3
Dia = 85 ±6km, 0.077"
Parallax = 5.814"
Hourly dRA =-1.830s
dDec =-16.97"

Occultation of 10.8-mag. star by (530) Turandot, 2020 July 27
Updated by JPL; this is the first, fainter event

This was another less publicized occultation by Turandot
That occurred only ~25 min. before the one shown on
The previous slide. Dave Gamble in Washington
Timed a 10s occultation not far from the
Central line, showing that the
Prediction for this event
Was also good, corroborated
By an 8.5s event timed by
Steve Preston near his home
~50 km north of the predicted center.
Paolo Tanga notes that this star had no problem
With its Gaia DR2 solution, and that it has very
different proper motion and parallax
compared with the other star, showing
that the two are not physically
related.

Prediction details at
http://www.asteroidoccultation.com/2020_07/0727_530_65594.htm



Occult 4.10.5.0, JPL#372020Jun25 Errors: Known errors

Further Improving Orbits with Asteroidal Occultation Observations

- MPC adapting ADES format that will finally give error information for occultation astrometry
- Handling gravitational deflection and other details
- To improve the ADES format

NEO Occultations – How Small?

- Paul Chodas wants us to discuss this
- We have the Phaethon experience
- Other NEO's that have been observed by Gaia, down to 1 km might be accessible with occ'ns
- Paul Chodas interested in events by larger NEO's, esp. (1866) Sisyphus, ~7km, no radar chance for it again until 2046
- Is there any chance of observing an occultation by a 100m object? Shape info. is unlikely, but even a single observation would be astrometrically valuable.

Asteroids whose orbits have been updated with Gaia and/or past occultations (with their small errors) by the JPL Horizons team

For future predictions, the JPL Horizons orbits with these special accurate updates should be used. But be sure that the orbit was not "erased" by a later automated update; you can tell since the errors will be much smaller for the correct orbits. The Lucky Star project is doing similar work for Trojan asteroids & more distant objects.

(16) Psyche
(55) Pandora
(110) Lydia ?
(191) Kolga
(303) Josephina
(363) Padua
(456) Abnoba
(479) Caprera
(530) Turandot
(1400) Tirela
(3200) Phaethon
(11351) Leucus – SwRI update, not JPL

More to come in the future, especially as processes become more automated. These will help before Gaia DR3 becomes available.

Future Occultations Needing Improvement

- Removed from this, specific events that are now past
- Objects of special interest - Phaethon, Lucy targets
- VERITAS in s. AZ observing at high speed to determine star ang. diameters; we can deploy stations to determine the size/shape of the asteroid to help their work. VERITAS has been closed mid March due to COVID rules & travel restrictions.
- Some occ’n searches to find a few bright events for NEO’s smaller than Phaethon. 15 largest NEO’s, esp. Sisyphus.
- TNO’s, Centaurs, some Trojans with Gaia observations; RECON and Lucky Star campaign events

IOTA meeting version of this presentation

- is 3rd from the bottom on the IOTA meeting page at www.occultations.org => COMMUNITY => meetings/conferences => 2020 IOTA N.Am. Meeting => Link to Presentations Page
- Or directly, http://occultations.org/community/meetingsconferences/na/2020-iota-annual-meeting/presentations-at-the-2020-annual-meeting/
- My longer presentation on the Phaethon occultations is also on that page, 4th from the bottom.
- If time, questions?