1 Gem (not Propus) mystery ...

The history of one observation

Wojciech Burzyński - SOPiZ PTMA, IOTA/ES

The best lunar graze of the year – ZC 916

It was supposed to be **the best** grazing occultation visible in Poland in 2020.

There were many reasons for this:
- a very bright 4th magnitude star
- the star was also known double, with bright components and large separation over 0.1”
- good Moon phase, only 19% illuminated
- large CA angle, nearly 11 degrees on the dark side

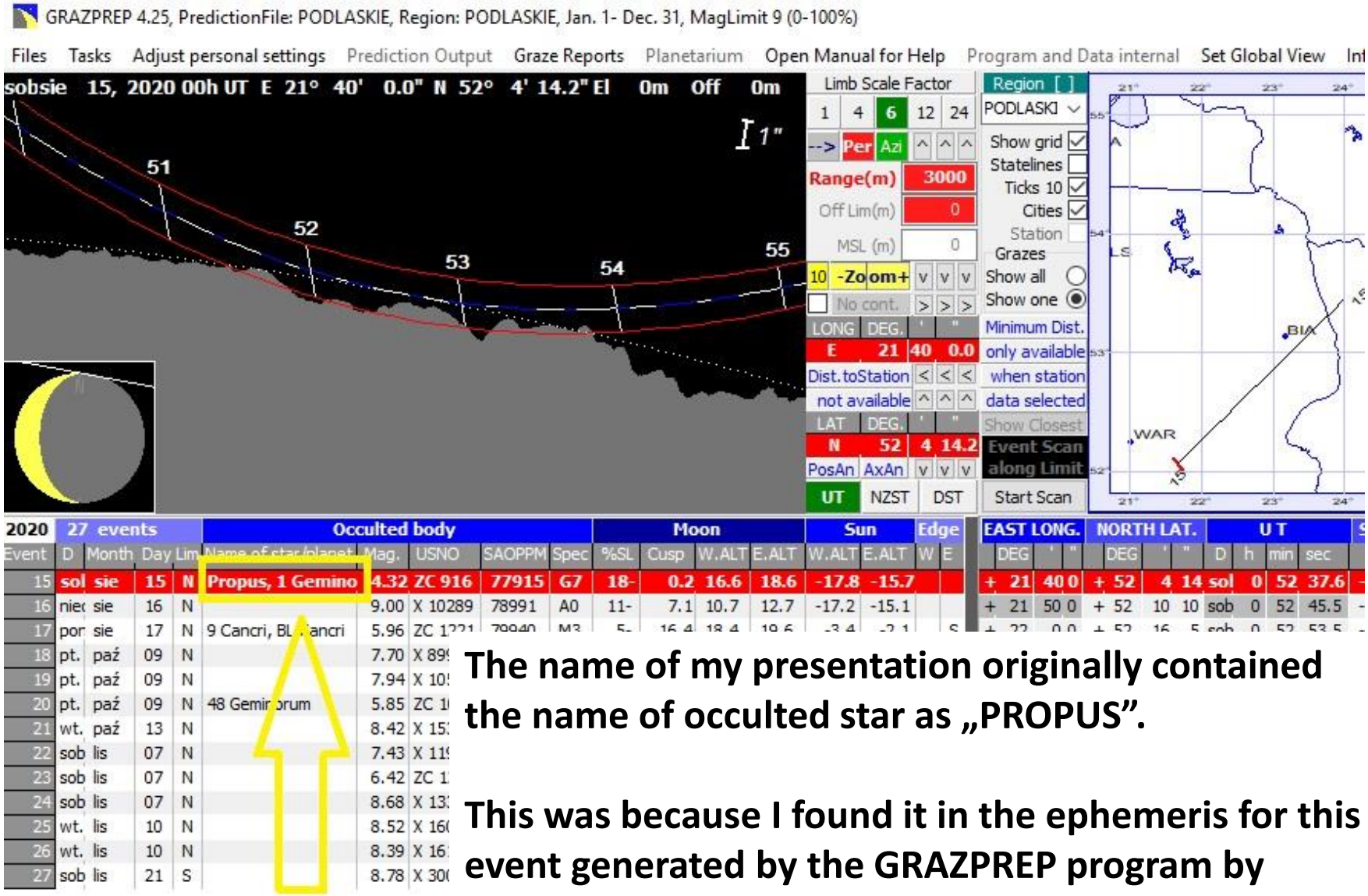
All these geometric conditions meant that the observers interest of the event was very high.

As usual, I started my double-check preparations much earlier:
- the ephemeris was carefully calculated using the latest Occult - v. 4.10.6.1
- then Occult’s ephemeris has been compared to the ephemeris of the GRAZPREP - v. 4.25

In both programs:
- observation sites & their distances from the limit line were calculated with an accuracy of 1m
- start & end times of the event were calculated for each observer with an accuracy of 1 s

As the graze limit line ran close to my city of Białystok, I also did the live –check of observation sites near the village of Rzepniki a few days earlier.

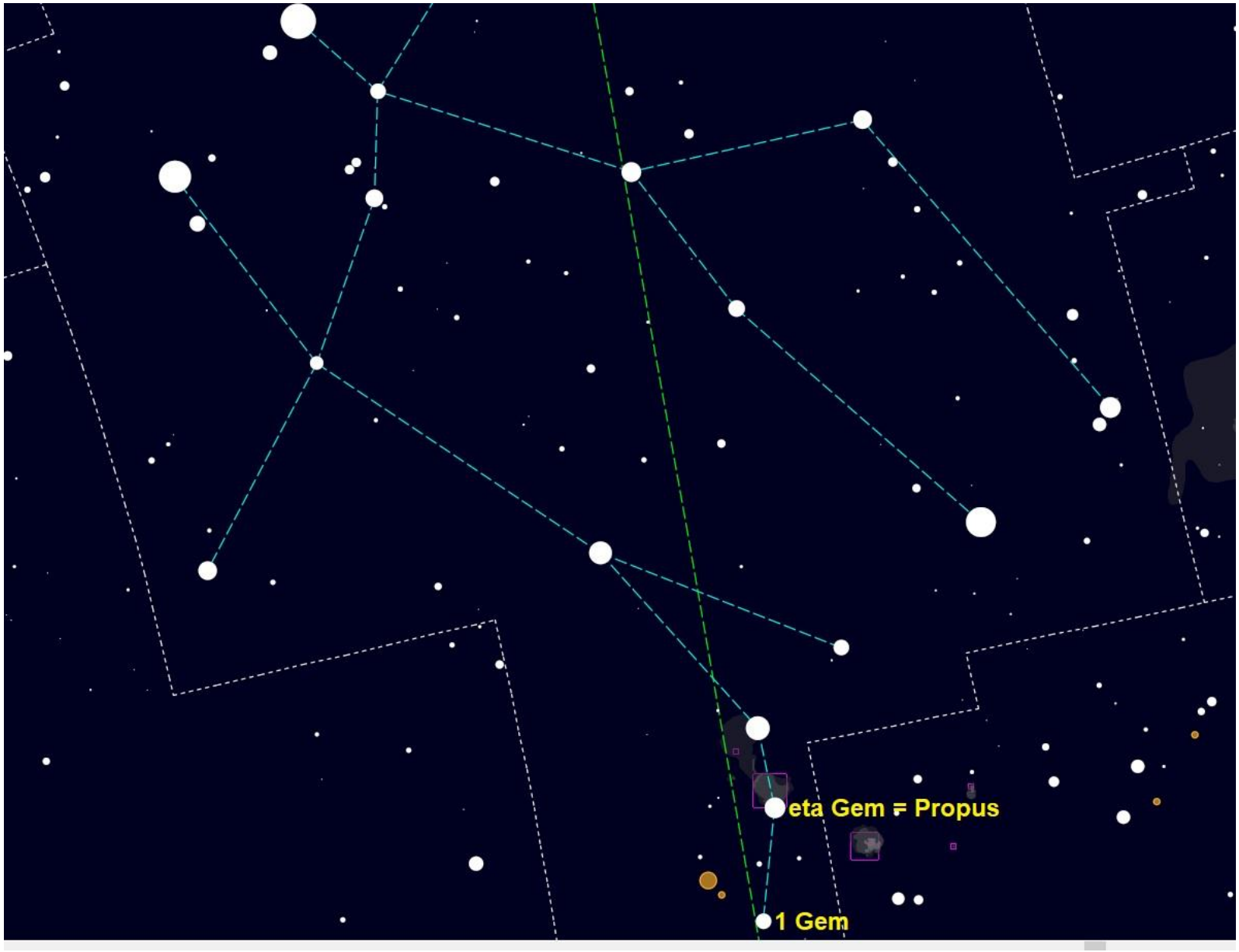
1 Gem is not Propus !



The name of my presentation originally contained the name of occulted star as „PROPUS”.

This was because I found it in the ephemeris for this event generated by the GRAZPREP program by Eberhard Riedel. In fact, the Propus is not 1 Gem!

Propus = eta Gem (3.3 mag)

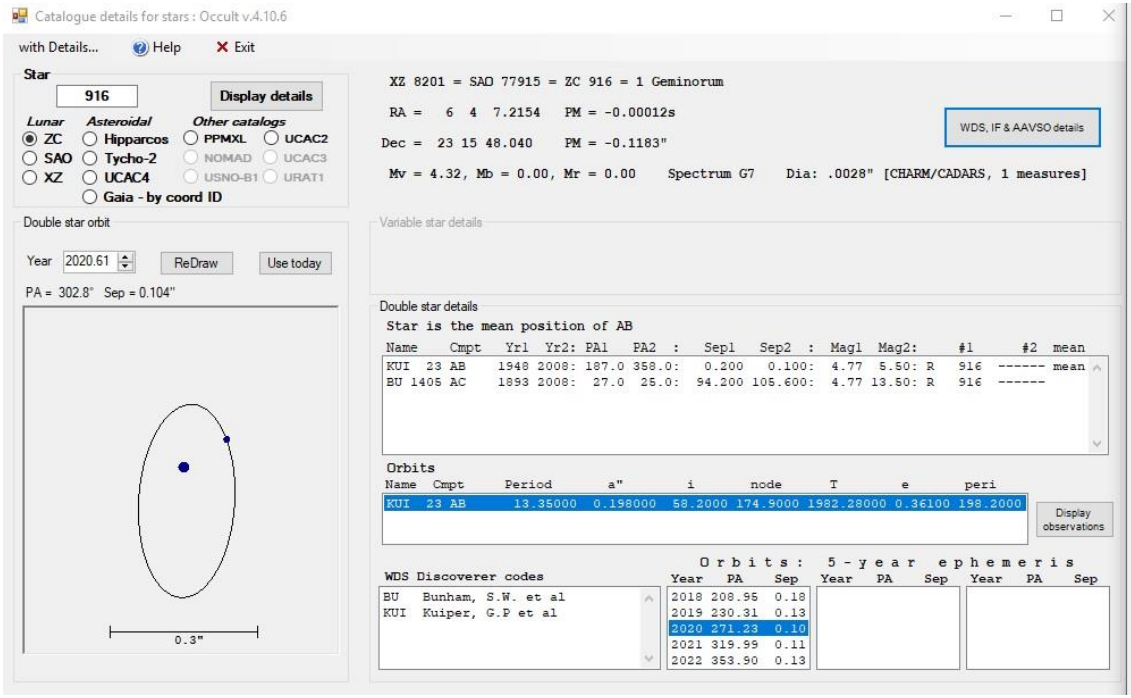


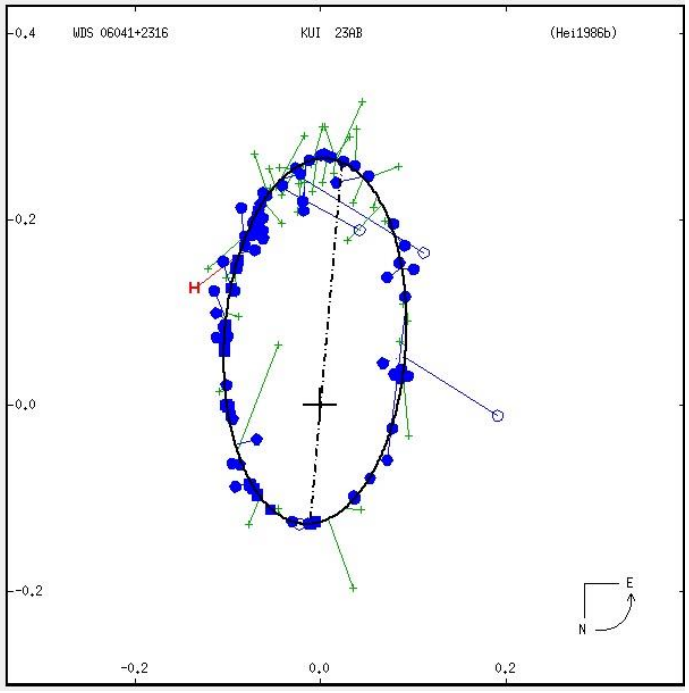
1 Geminorum – double star with an orbit

1 Geminorum = ZC 916 = XZ 8201 = HIP 28734 = SAO 77915

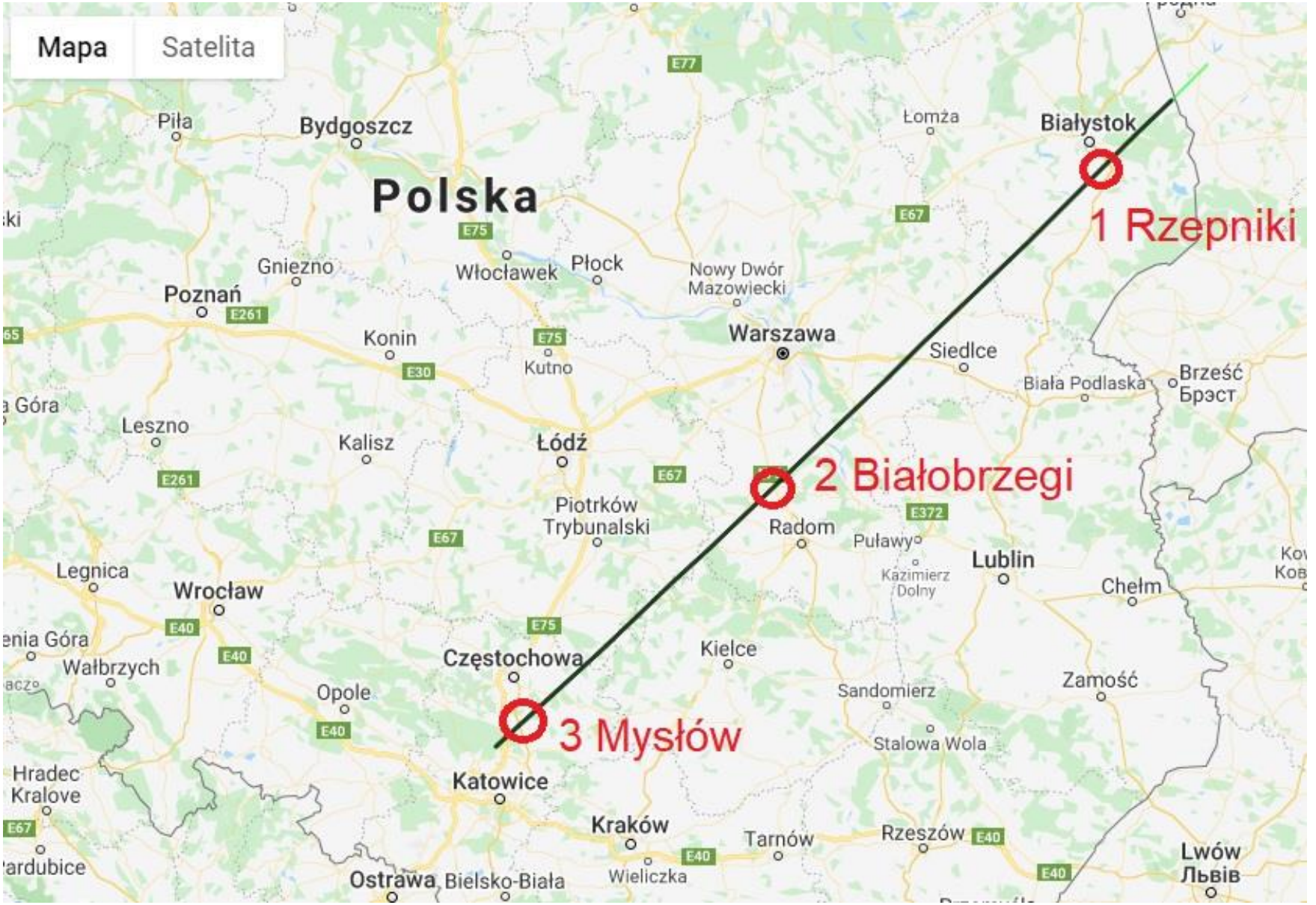
V = 4.32 mag
Diameter = 0.0028” (projected diameter of star = 8 meters)

Double star: A = 4.77 mag, B = 5.50 mag, C = 13.5 mag
Separation AB = 0.104” , PA = 303.2 , Period = 13.35 y
Graze path of B approximately 0.2 km south, and 0.1 secs earlier compared to A
Separation AC: 107” , PA: 24.8

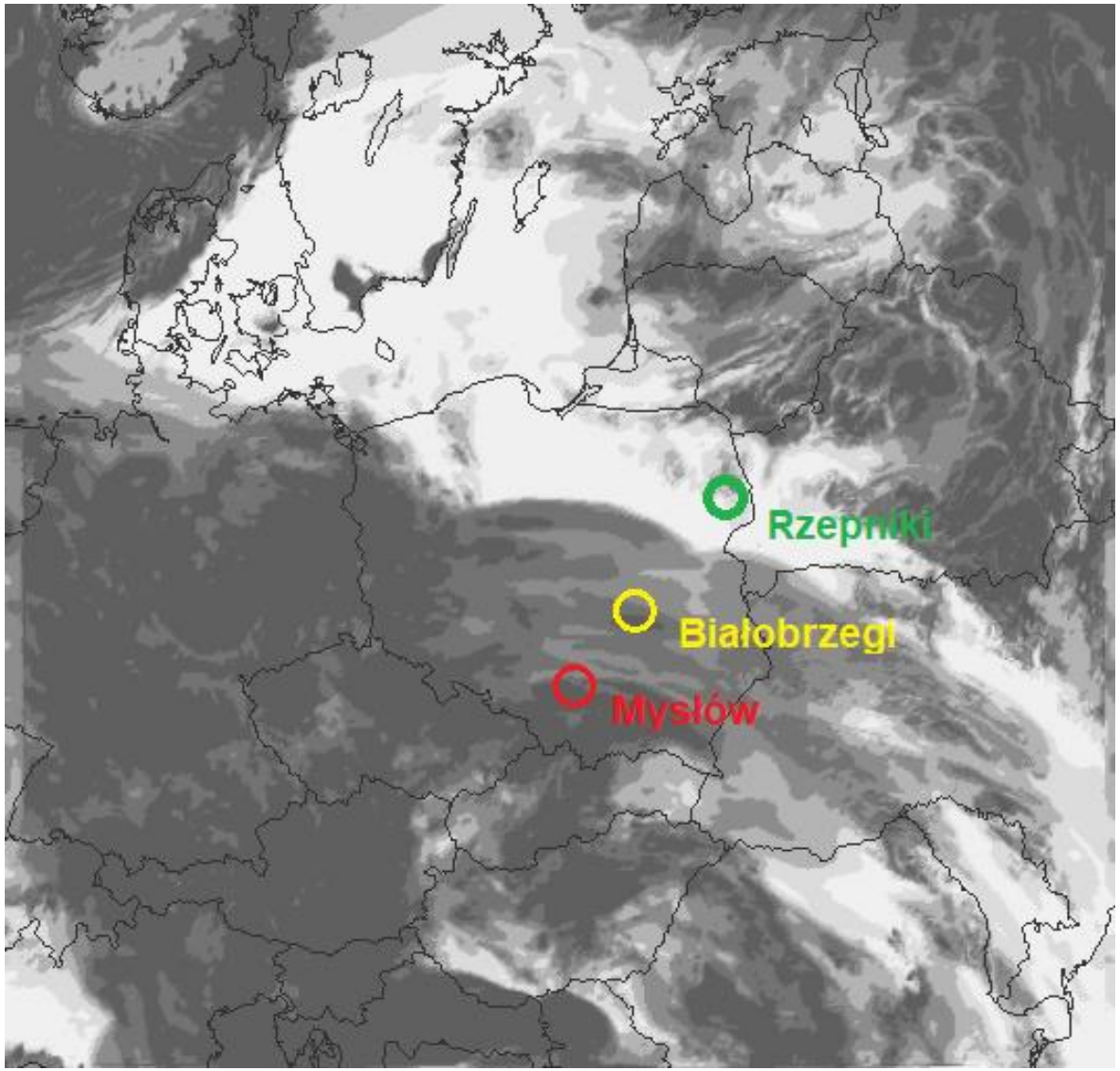




Preparation – 3 independent sites



Preparation – weather foracast



Rzepniki:
0-10 % cloud cover
5 stations

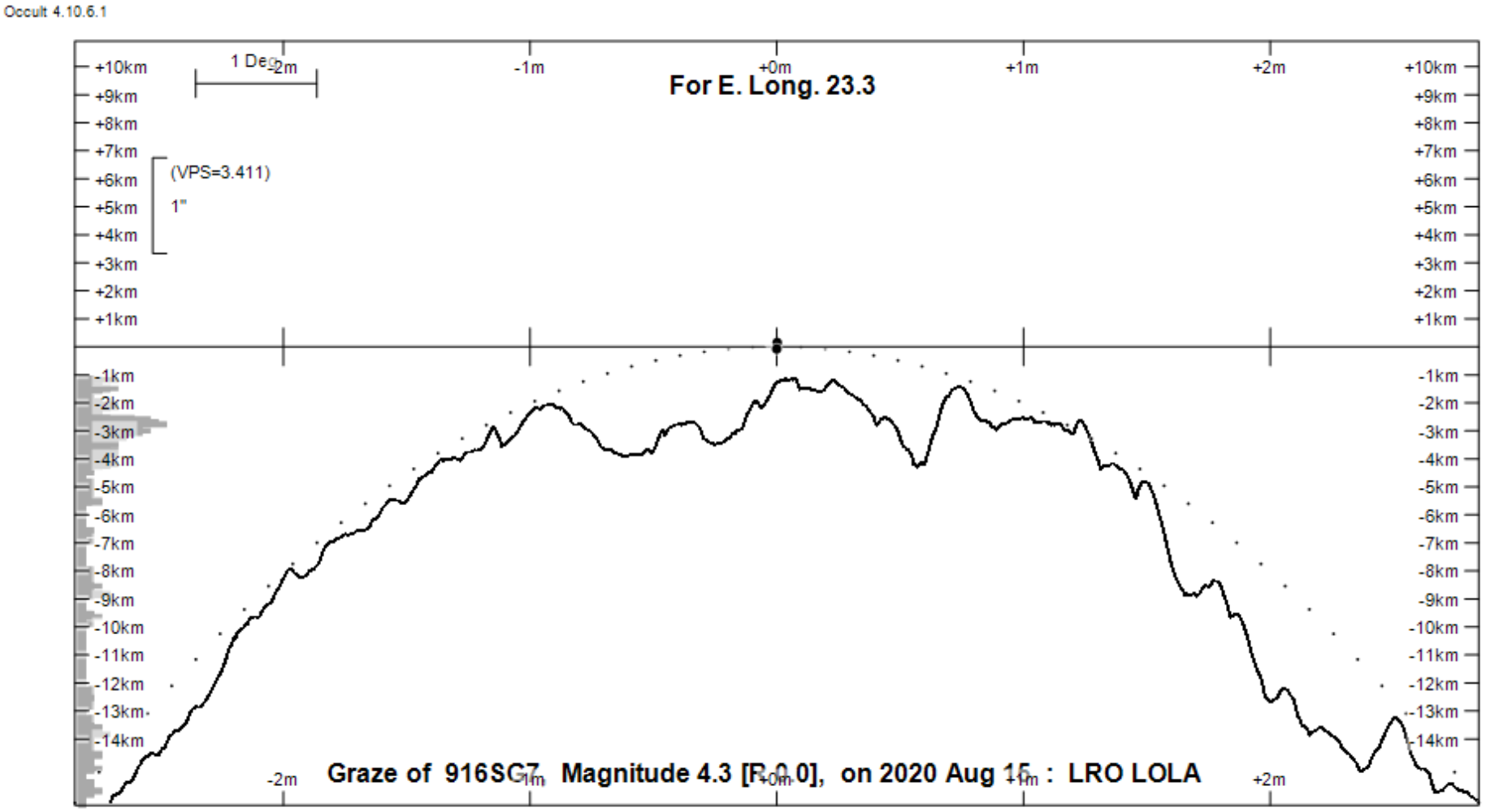
Białobrzegi:
50% cloud civer
2 stations + ONLINE

Mysłów:
50 - 100 % cloud cover

Mysłów station has been cancelled!

Preparation – Moon profile

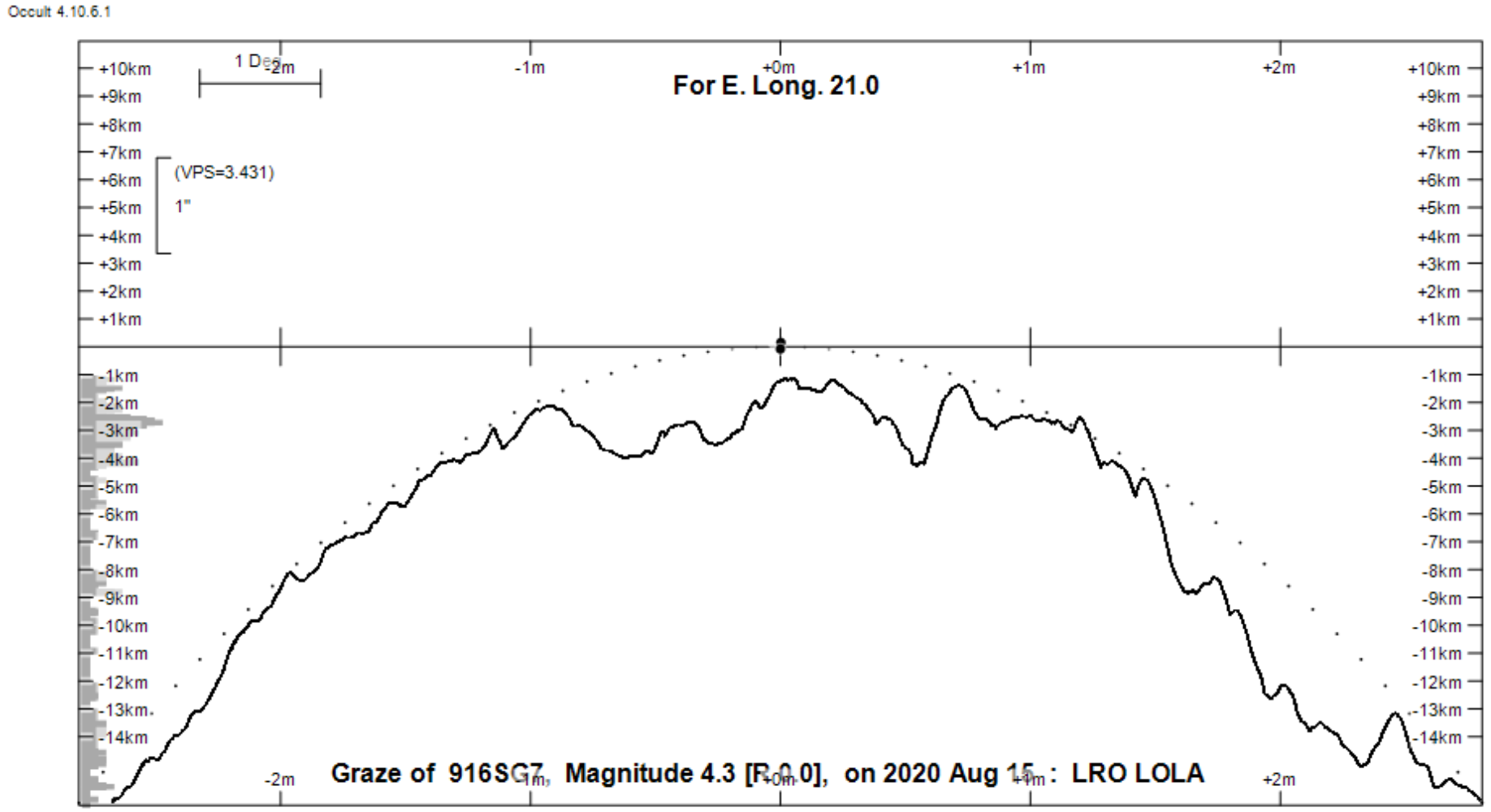
Rzepniki site



Preparation – Moon profile

Białobrzegi site

(Rzepniki-Białobrzegi distance = 213 km)



Preparation – Moon profile
vertical scale enlarged by 3.5x

The best part between 2.6 km and 3.6 km has been chosen for observation

Occult vs GRAZPREP ephemeris

					GRAZPREP			OCCULT		
STN	OBSERVER	LON	LAT	H	DIST.	TIMES	EVENTS	DIST.	TIMES	EVENTS
No	Name	WGS'84	WGS'84	[m]	[km]	[UT]	No	[km]	[UT]	No
RZEPNIKI site - NE Poland										
1	Wojciech Burzynski	23 12 59.3	52 57 20.6	142	2.532 km	00:52:47.7 - 00:55:05.0	12	2.602 km	00:52:49.4 - 00:55:05.9	12 +
2	Maciej Jarmoc	23 12 58.8	52 57 14.9	142	2.651 km	00:52:47.0 - 00:55:05.2	14	2.720 km	00:52:48.8 - 00:55:06.1	12
3	Maciej Borkowski	23 12 57.9	52 57 03.2	142	2.896 km	00:52:39.8 - 00:55:05.7	14	2.966 km	00:52:41.0 - 00:55:06.6	10 to 12
4	Adam Reducha	23 12 53.0	52 56 49.6	140	3.132 km	00:52:38.1 - 00:55:05.7	10	3.201 km	00:52:40.0 - 00:55:06.9	10
5	Oskar Kielczyk	23 12 52.3	52 56 31.6	142	3.517 km	00:52:36.6 - 00:55:06.2	6	3.588 km	00:52:36.6 - 00:55:07.3	6 to 8
BIAŁOBRZEGI site - central Poland										
1	Marcin Gorko	20 57 24.7	51 37 52.4	140	1.360 km	00:52:00.4 - 00:52:17.8	4	1.430 km	00:52:01.7 - 00:52.19.2	6
2	Marek Zawilski	20 58 23.7	51 37 14.4	138	2.989 km	00:50:51.5 - 00:53:15.7	10	3.057 km	00:50:52.9 - 00:53:16.8	8 to 10

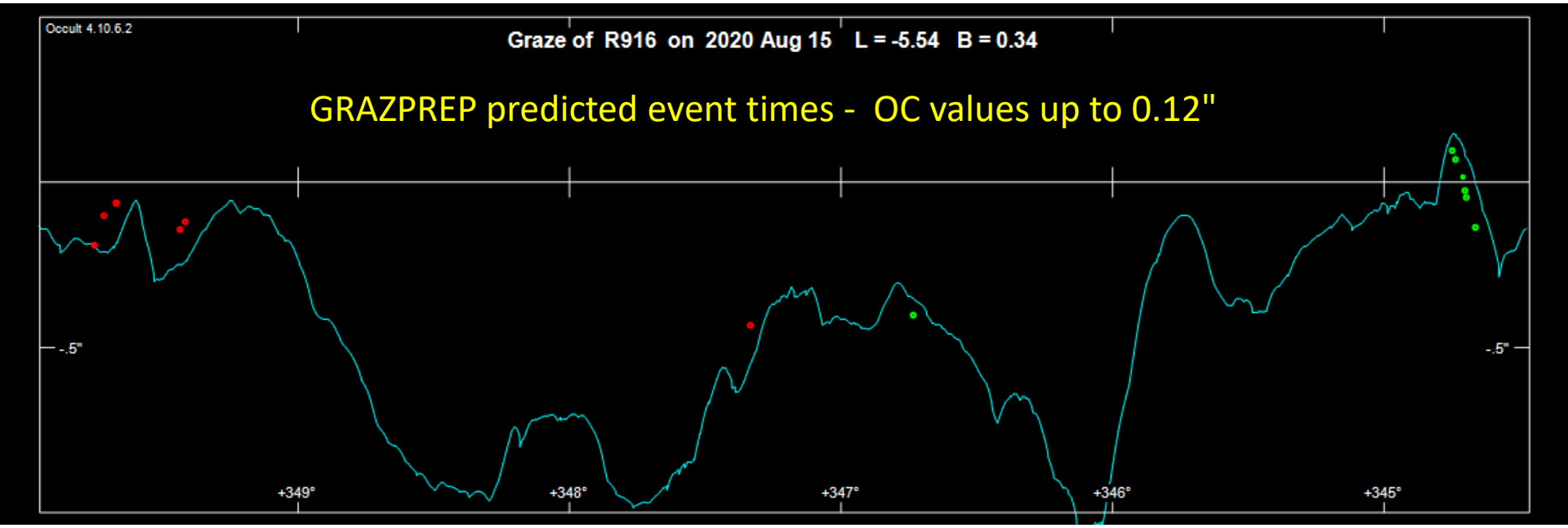
GRAZREP program calculates times, number of all events and the distance of the station from the graze limit line itself after entering coordinates and altitude of each station.

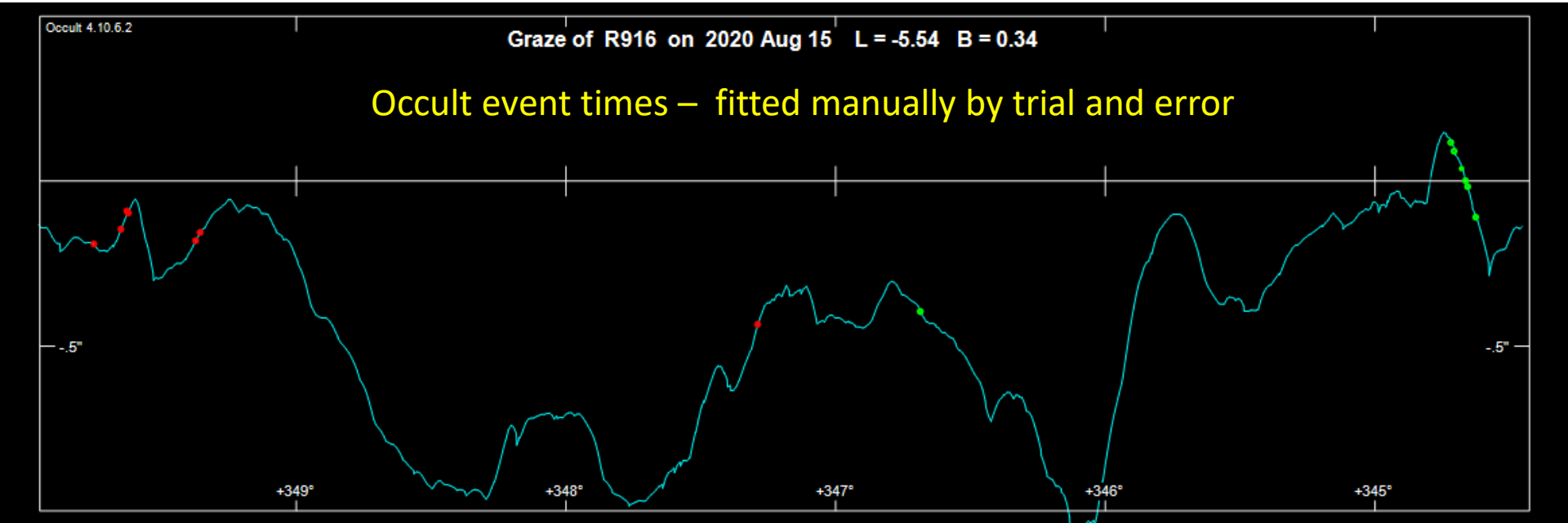
OCCULT start & end event times were calculated manually by trial and error. For each station, the first and last event were adjusted so that the moment residual was as small as possible. In this case, the highest OC residuum value was not greater than 0.013".

The station distances from the graze limit line were calculated with the HTML file generated by Occult for the average height of all sites of 142 m. I had to estimate number of events myself.

The GRAZPREP event times are earlier than the Occult event times by 1-2 sec.
The GRAZPREP graze limit line is approximately 70 m north of that calculated by Occult.

Predicted event times against the LRO profile





LIVE broadcast by Karol Wójcicki

Several meters from M. Zawilski's station was **Karol Wójcicki**, a well- known reporter and popularizer of astronomy in Poland, author of the FB fanpage „Head in the stars".

LIVE broadcast were watched by 242 people at the peak!

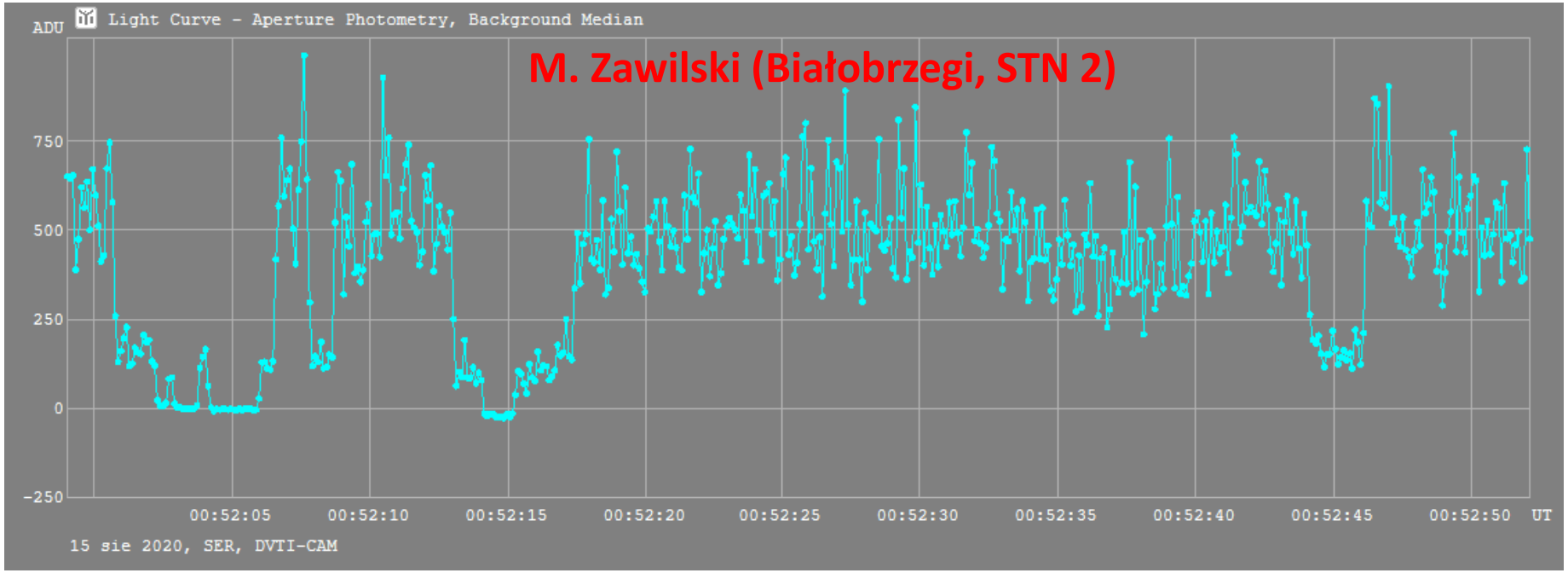
The current (Aug 28, 2020) range of this recording is about 62 thousand views.

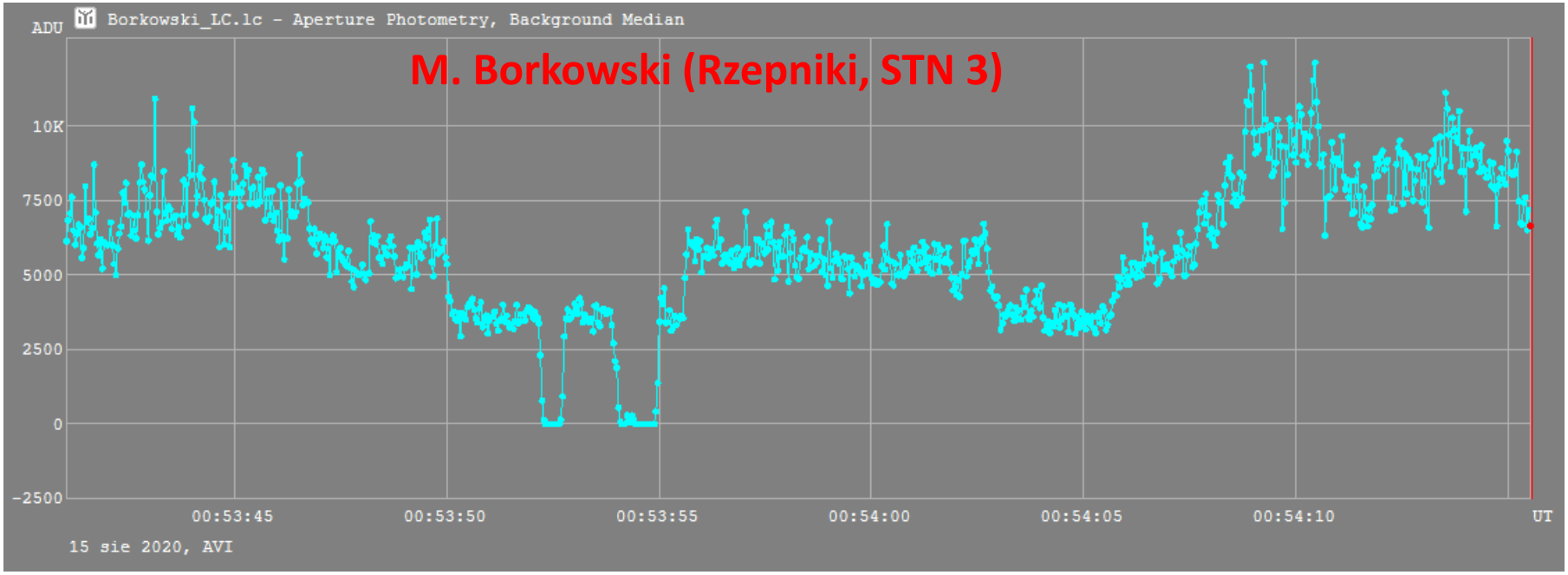
Preparation – Rzepniki, Białystok region

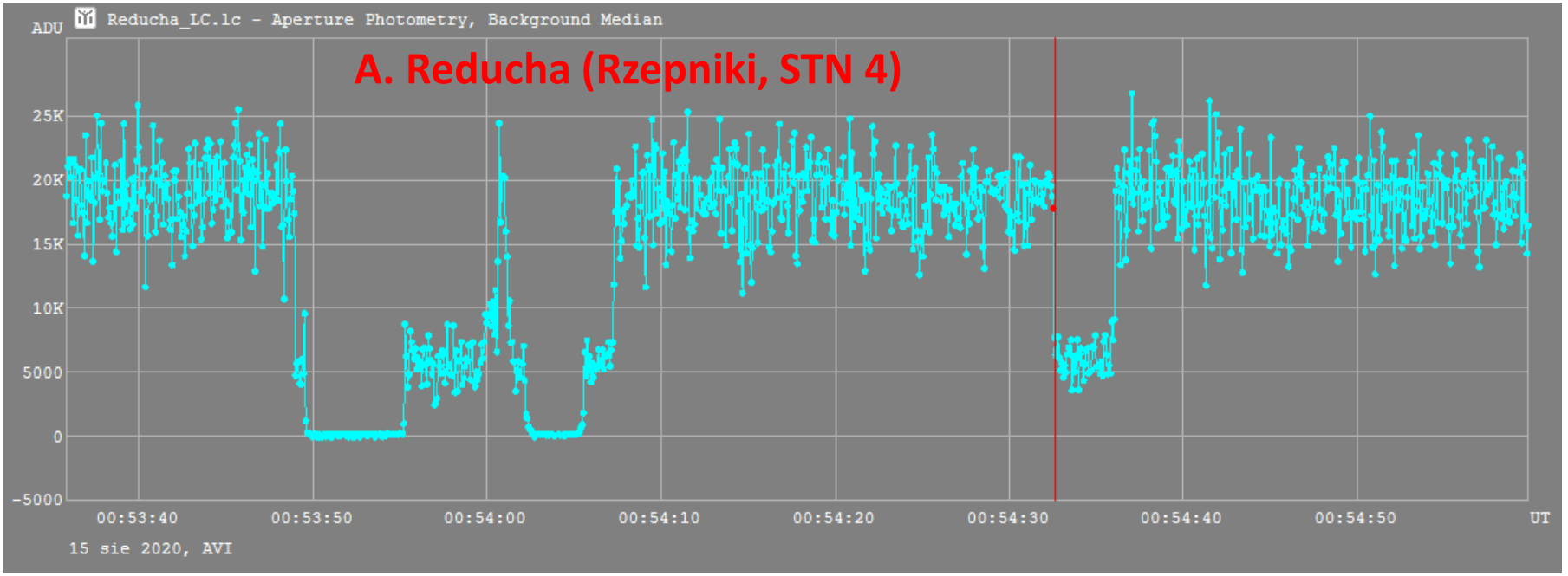
Results – light curves

The recording results of all positive observers clearly show doubleness of the star.

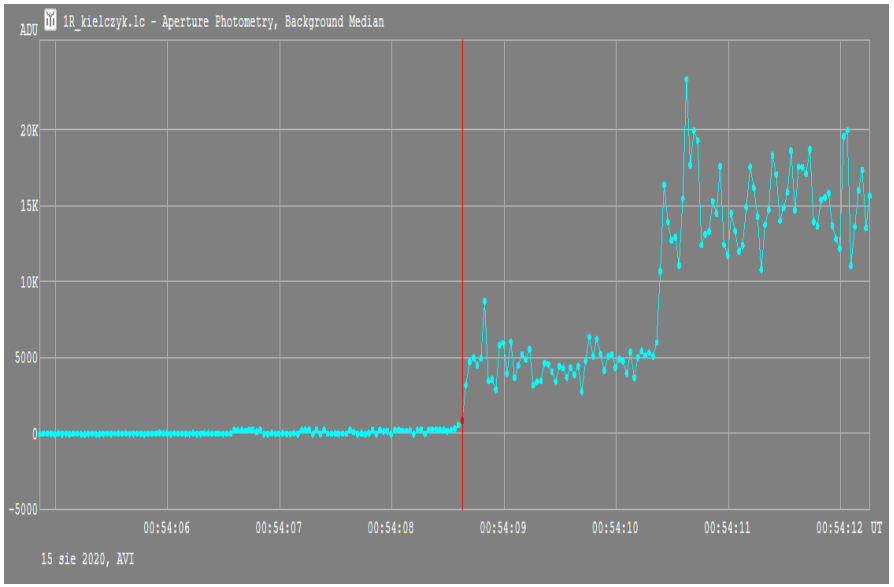
DISAPPEAR = 21
REAPPEAR = 21
FLASH = 4
BLINK = 1
MISS = 3 stations

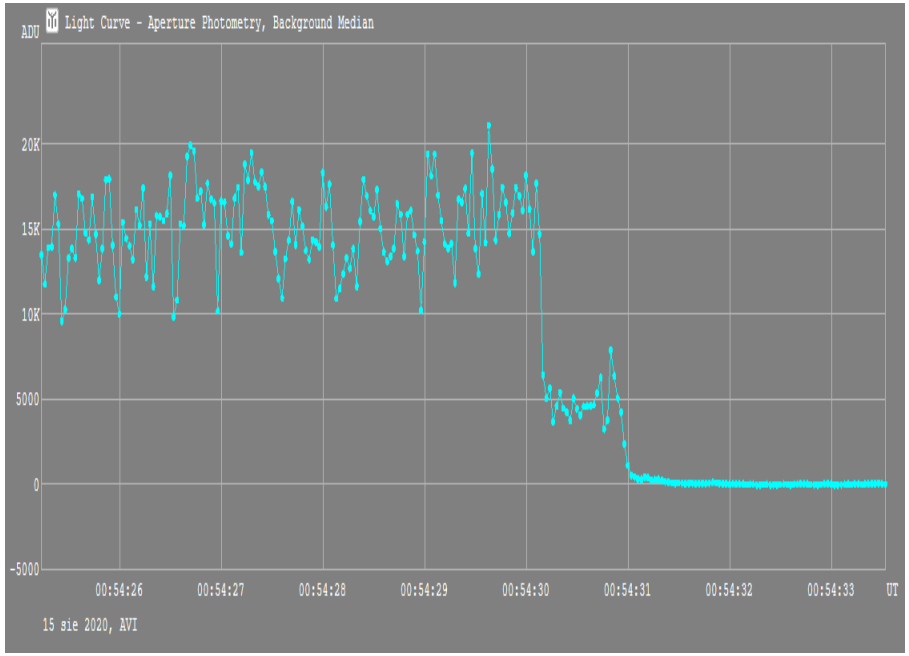


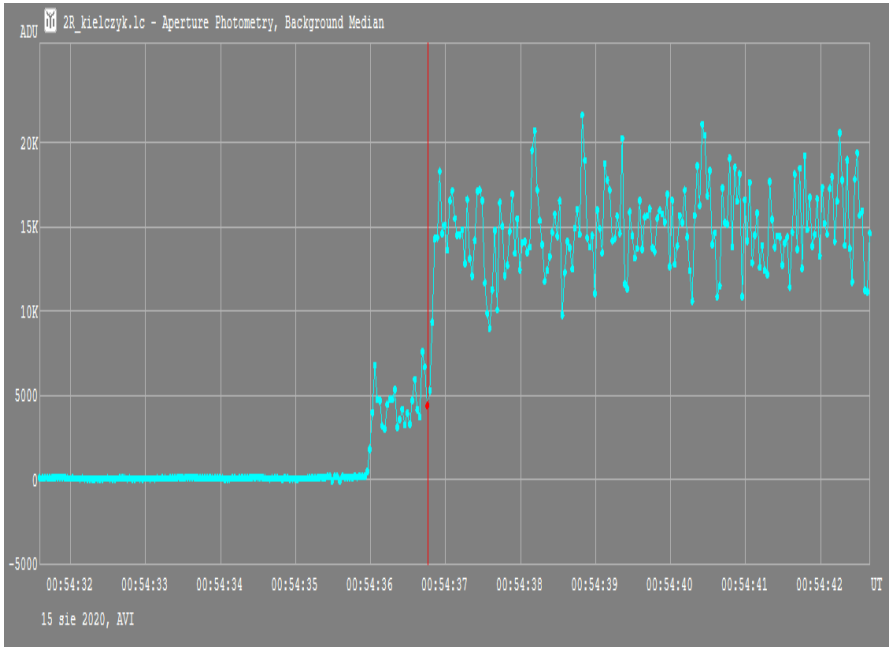

Borkowski_LC.lc - Aperture Photometry, Background Median
M. Borkowski (Rzepniki, STN 3)
ADU
10K
7500
5000
2500
0
-2500
00:53:45
00:53:50
00:53:55
00:54:00
00:54:05
00:54:10
UT
15 sie 2020, AVI


Reducha_LC.lc - Aperture Photometry, Background Median
A. Reducha (Rzepniki, STN 4)
ADU
25K
20K
15K
10K
5000
0
-5000
00:53:40
00:53:50
00:54:00
00:54:10
00:54:20
00:54:30
00:54:40
00:54:50
UT
15 sie 2020, AVI

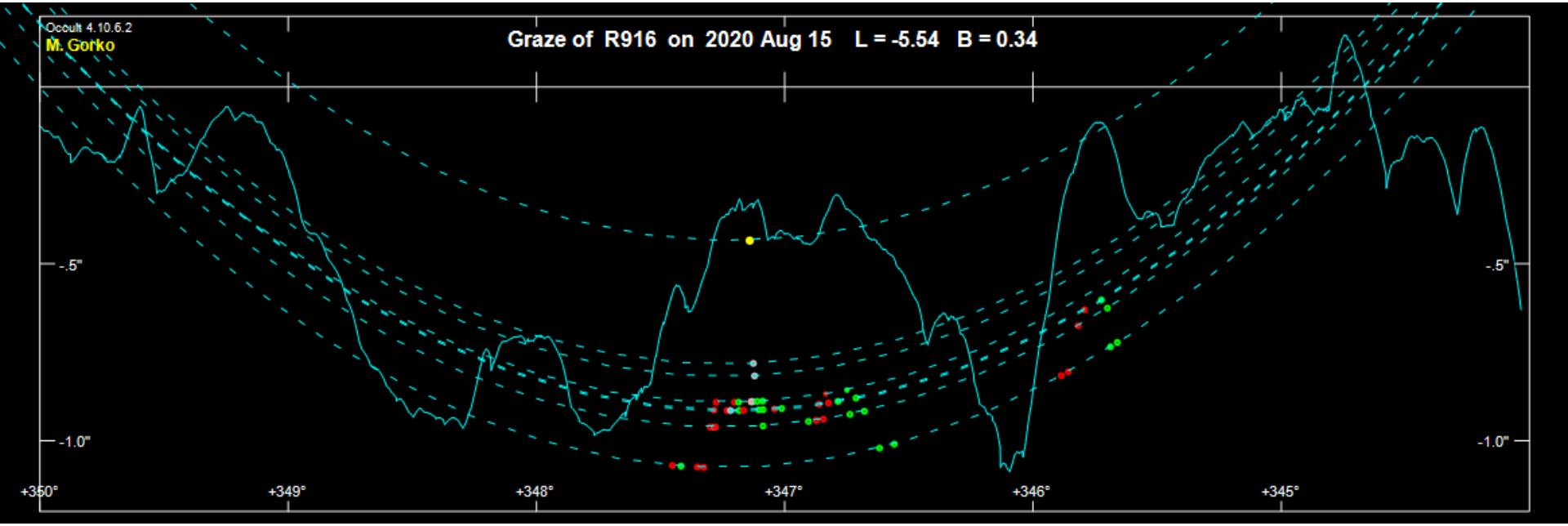
O. Kielczyk (Rzepniki, STN 5)

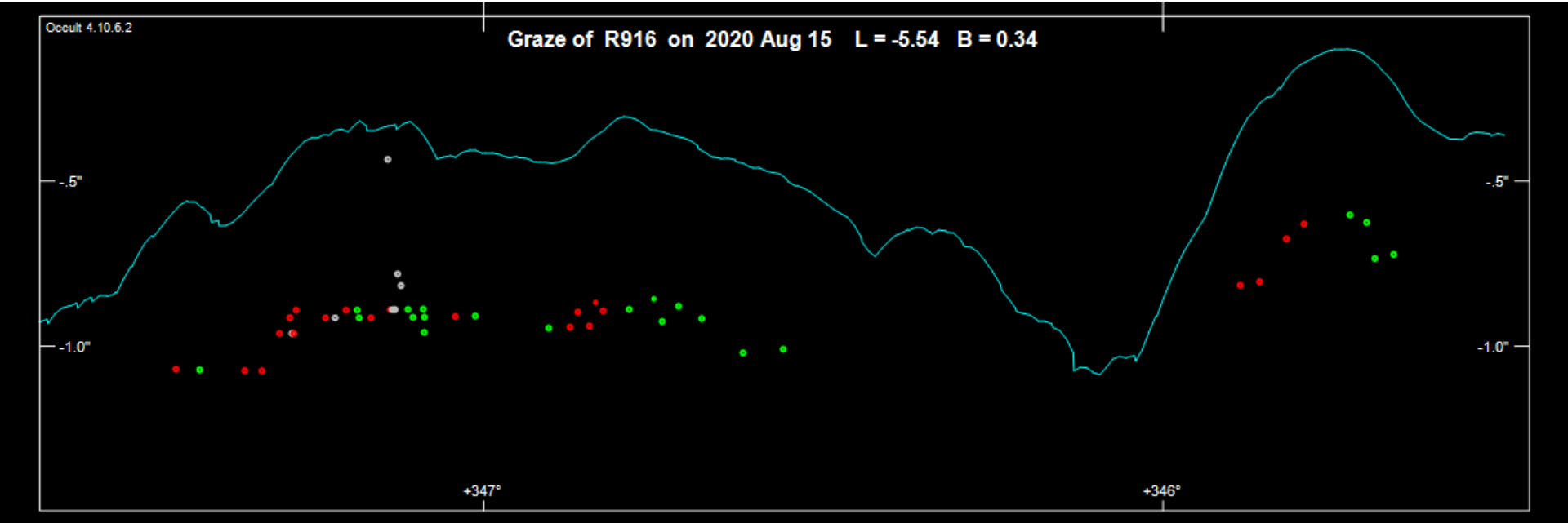






Overall results – events .... ?!?





Overall results – OC values

ref	Tel	Observer	Star	No.	y	m	d	h	m	s	PhGrMrCeDb	O-C mas	O-C sec	limb "
001	A	W. Burzynski	R	916	2020	8	15	0	53	55	MD G G 1	-451	-35.95	-0.33
002	B	M. Jarmoc	R	916	2020	8	15	0	53	55	MD G G 1	-489	-11.62	-0.33
003	C	M. Borkowski	R	916	2020	8	15	0	53	50.15	DD G G 1 W	-494	17.83	-0.39
004	C	M. Borkowski	R	916	2020	8	15	0	53	52.31	DD G G 1 E	-540	31.10	-0.35
005	C	M. Borkowski	R	916	2020	8	15	0	53	52.79	RD G G 1 E	-572	-25.87	-0.32
006	C	M. Borkowski	R	916	2020	8	15	0	53	54.23	DD G G 1 E	-556	45.62	-0.33
007	C	M. Borkowski	R	916	2020	8	15	0	53	54.31	FD G G 1 E	-559	-60.46	-0.33
008	C	M. Borkowski	R	916	2020	8	15	0	53	54.39	BD G G 1 E	-559	-60.28	-0.33
009	C	M. Borkowski	R	916	2020	8	15	0	53	54.43	FD G G 1 E	-559	-60.19	-0.33
010	C	M. Borkowski	R	916	2020	8	15	0	53	54.99	RD G G 1 E	-568	-6.81	-0.32
011	C	M. Borkowski	R	916	2020	8	15	0	53	55.65	RD G G 1 W	-520	-8.41	-0.37
012	C	M. Borkowski	R	916	2020	8	15	0	54	3.11	DD G G 2 W	-505	11.18	-0.36
013	C	M. Borkowski	R	916	2020	8	15	0	54	5.63	RD G G 2 W	-510	-20.87	-0.34
014	D	A. Reducha	R	916	2020	8	15	0	53	49.08	DD G G 1 W	-488	5.21	-0.47
015	D	A. Reducha	R	916	2020	8	15	0	53	49.62	FD G G 1 W	-543	11.17	-0.42
016	D	A. Reducha	R	916	2020	8	15	0	53	49.70	DD G G 1 E	-543	11.18	-0.42
017	D	A. Reducha	R	916	2020	8	15	0	53	55.34	RD G G 1 E	-590	-9.54	-0.37
018	D	A. Reducha	R	916	2020	8	15	0	54	0.73	RD G G 1 W	-501	39.87	-0.44
019	D	A. Reducha	R	916	2020	8	15	0	54	1.65	DD G G 1 W	-514	10.16	-0.43
020	D	A. Reducha	R	916	2020	8	15	0	54	2.49	DD G G 1 E	-562	13.20	-0.37
021	D	A. Reducha	R	916	2020	8	15	0	54	5.64	RD G G 1 E	-572	-24.61	-0.35
022	D	A. Reducha	R	916	2020	8	15	0	54	7.35	RD G G 1 W	-513	-14.53	-0.40
023	D	A. Reducha	R	916	2020	8	15	0	54	32.67	DD G G 1 W	-487	13.20	-0.19
024	D	A. Reducha	R	916	2020	8	15	0	54	36.15	RD G G 1 W	-498	-6.93	-0.13
025	E	O. Kielczyk	R	916	2020	8	15	0	53	44.12	DD G G 1 W	-475	25.04	-0.59
026	E	O. Kielczyk	R	916	2020	8	15	0	53	45.15	RD G G 1 W	-494	-8.79	-0.58
027	E	O. Kielczyk	R	916	2020	8	15	0	53	47.10	DD G G 1 W	-492	7.62	-0.58
028	E	O. Kielczyk	R	916	2020	8	15	0	53	47.84	DD G G 1 E	-536	5.56	-0.54
029	E	O. Kielczyk	R	916	2020	8	15	0	54	8.66	RD G G 1 E	-573	-19.02	-0.44
030	E	O. Kielczyk	R	916	2020	8	15	0	54	10.40	RD G G 1 W	-530	-10.35	-0.48
031	E	O. Kielczyk	R	916	2020	8	15	0	54	30.19	DD G G 1 W	-472	6.97	-0.34
032	E	O. Kielczyk	R	916	2020	8	15	0	54	31.03	DD G G 1 E	-541	9.75	-0.26
033	E	O. Kielczyk	R	916	2020	8	15	0	54	36.02	RD G G 1 E	-590	-7.29	-0.14
034	E	O. Kielczyk	R	916	2020	8	15	0	54	36.84	RD G G 1 W	-517	-4.71	-0.20
035	F	M. Zawilski	R	916	2020	8	15	0	52	0.69	DD G G 1 W	-495	10.23	-0.42
036	F	M. Zawilski	R	916	2020	8	15	0	52	2.22	DD G G 1 E	-554	37.69	-0.36

This is only part of results reduction.

There are 50 rows in total.

Average OC value of 50 events (misses included):

- 0.52"

What happened? – D. Herald explanation

We have had an extremely rare and unlucky situation !

The star is not in Gaia DR2.
The star position used in the Occult Gaia subsets comes from old **Hipparcos** catalog.

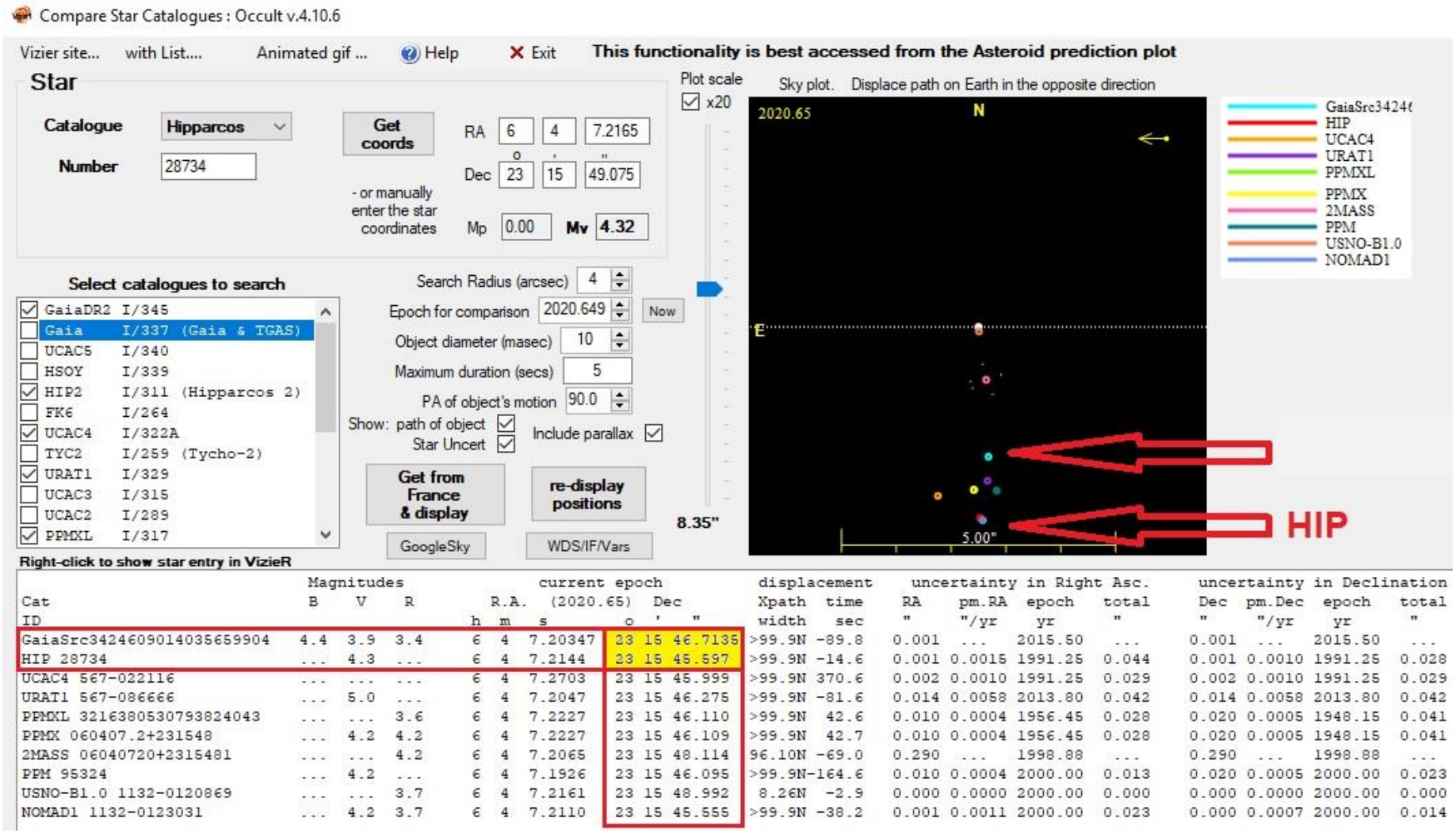
The Hipparcos position referred to 2000 is *6 04 07.215 +23 15 48.04*
The old ZC position, referenced to the 2000 equinox is *6 04 07.184 +23 15 47.76*

The difference of about 0.3" in DEC and 0.4" in RA.
If the old ZC catalogue had been used, the predicted path would have lined up with our data.

The ZC catalogue has an annual proper motion in dec of –0.1044", whereas Hipparcos has –0.1183 (a difference of 0.0139" per year). The resulting difference at 2020 (which has to be taken from the Hipparcos epoch of 1991.25) is 0.40" – consistent with the observed difference.

It would seem that the solution for the main component was treated as a linear movement in RA & DEC. If the double had a long period, this would be OK. But with such a short period of 13 years (2 revolutions since Hipparcos) the proper motion would have been determined by the star's difference in position between Nov 1989 and Mar 1993 (the mission duration) which is affected by the orbital motion over that period. This has given the incorrect position we now have when Hipparcos is used for the star's position.

1 Gem – Occult astrometry data



Right-click to show star entry in VizieR

Cat ID	Magnitudes B	V	R	current epoch (2020.65) R.A. h m s	Dec ° ' "	displacement Xpath width	time sec	uncertainty in Right Asc. RA "	pm.RA "/yr	epoch yr	total "	uncertainty in Declination Dec "	pm.Dec "/yr	epoch yr	total "
GaiaSrc3424609014035659904	4.4	3.9	3.4	6 4 7.20347	23 15 46.7135	>99.9N	-89.8	0.001	...	2015.50	...	0.001	...	2015.50	...
HIP 28734	...	4.3	...	6 4 7.2144	23 15 45.597	>99.9N	-14.6	0.001	0.0015	1991.25	0.044	0.001	0.0010	1991.25	0.028
UCAC4 567-022116	...	...	...	6 4 7.2703	23 15 45.999	>99.9N	370.6	0.002	0.0010	1991.25	0.029	0.002	0.0010	1991.25	0.029
URAT1 567-086666	...	5.0	...	6 4 7.2047	23 15 46.275	>99.9N	-81.6	0.014	0.0058	2013.80	0.042	0.014	0.0058	2013.80	0.042
PPMXL 3216380530793824043	...	...	3.6	6 4 7.2227	23 15 46.110	>99.9N	42.6	0.010	0.0004	1956.45	0.028	0.020	0.0005	1948.15	0.041
PPMX 060407.2+231548	...	4.2	4.2	6 4 7.2227	23 15 46.109	>99.9N	42.7	0.010	0.0004	1956.45	0.028	0.020	0.0005	1948.15	0.041
2MASS 06040720+2315481	...	...	4.2	6 4 7.2065	23 15 48.114	96.10N	-69.0	0.290	...	1998.88	...	0.290	...	1998.88	...
PPM 95324	...	4.2	...	6 4 7.1926	23 15 46.095	>99.9N	-164.6	0.010	0.0004	2000.00	0.013	0.020	0.0005	2000.00	0.023
USNO-B1.0 1132-0120869	...	...	3.7	6 4 7.2161	23 15 48.992	8.26N	-2.9	0.000	0.0000	2000.00	0.000	0.000	0.0000	2000.00	0.000
NOMAD1 1132-0123031	...	4.2	3.7	6 4 7.2110	23 15 45.555	>99.9N	-38.2	0.001	0.0011	2000.00	0.023	0.000	0.0007	2000.00	0.014

Is the star in Gaia DR2 or not?

The difference in declination between Gaia (DR2?) and HIP2 exceeds 1"

Make TEST STATIONS (trial and error)

In next step, I decided that by trial and error I would try to adjust the coordinates of each station (make TEST STATIONS) so that the measured real event times would fit best to lunar LRO profile.

Looking at very strange results, I knew I had to move to the station position quite significantly, over 1.5 km to the north.

Then I tried to select coordinates of choosen site several times using Google Earth.

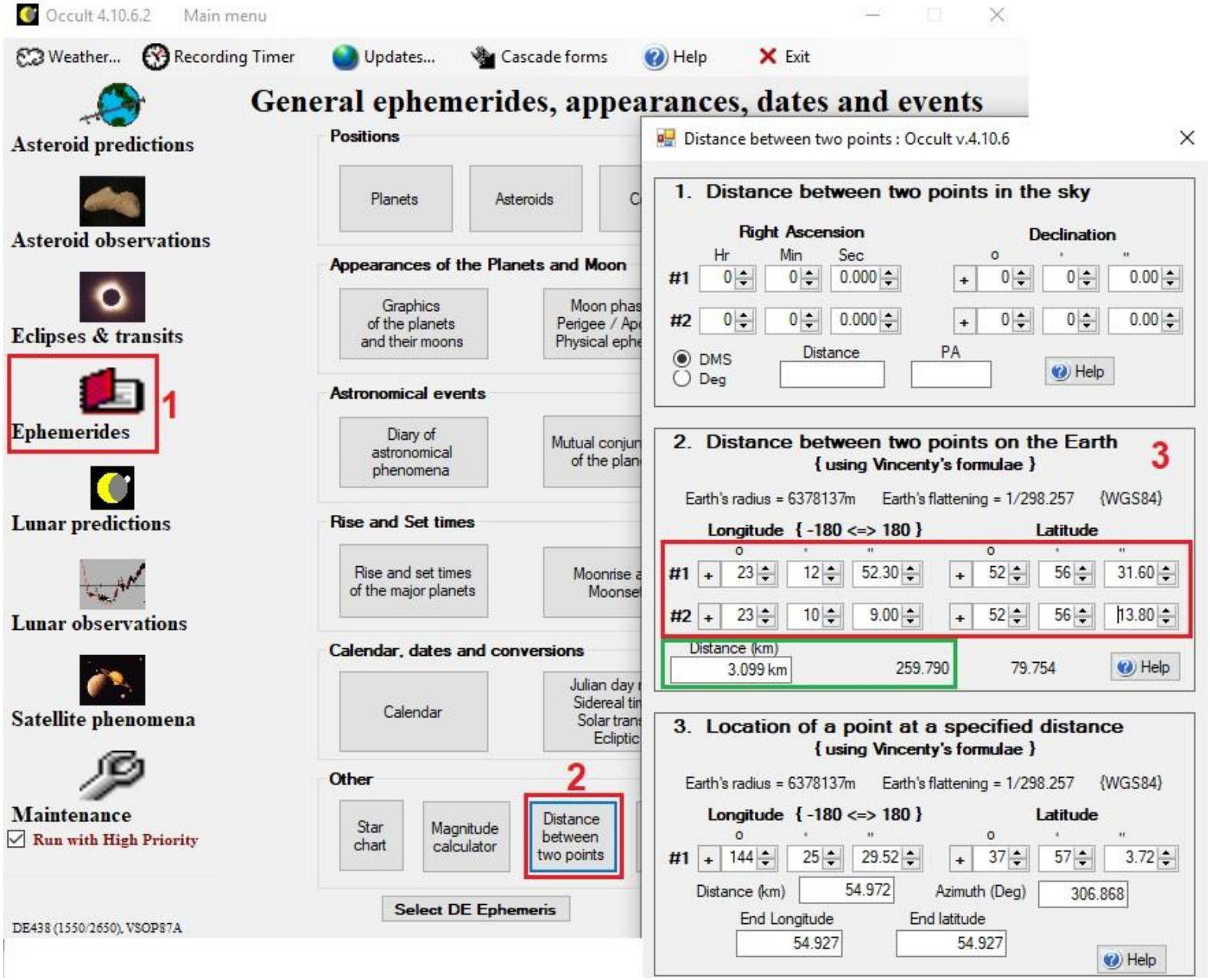
Finally, I determined the value of the geographic coordinates of Oskar Kielczyk's **TEST** site so that the OC values of his observations were as low as possible.

Then I used the formula in Occult to calculate the distance and azimuth angle between 2 points (between the real site and TEST site of O. Kielczyk).

Assuming that **SHIFT** value would be the same for all stations, I used another Occult formula and calculated the coordinates of all TEST stations.

Approximately: **SHIFT = 3.099 km, Azimuth = 259.79 deg**

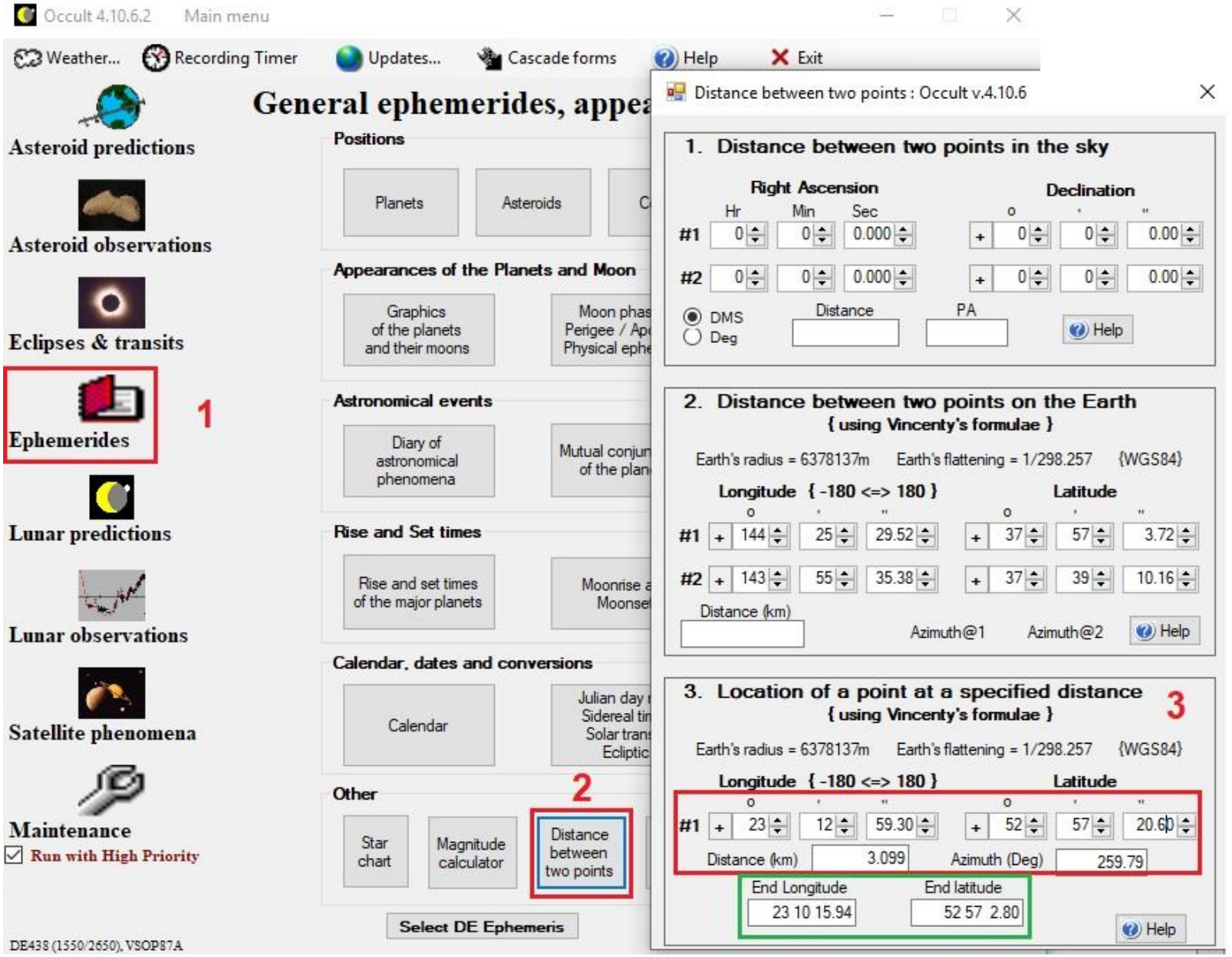
O. Kielczyk TEST STATION (trial and error)



SHIFT
3.099 km

Azimuth
259.79

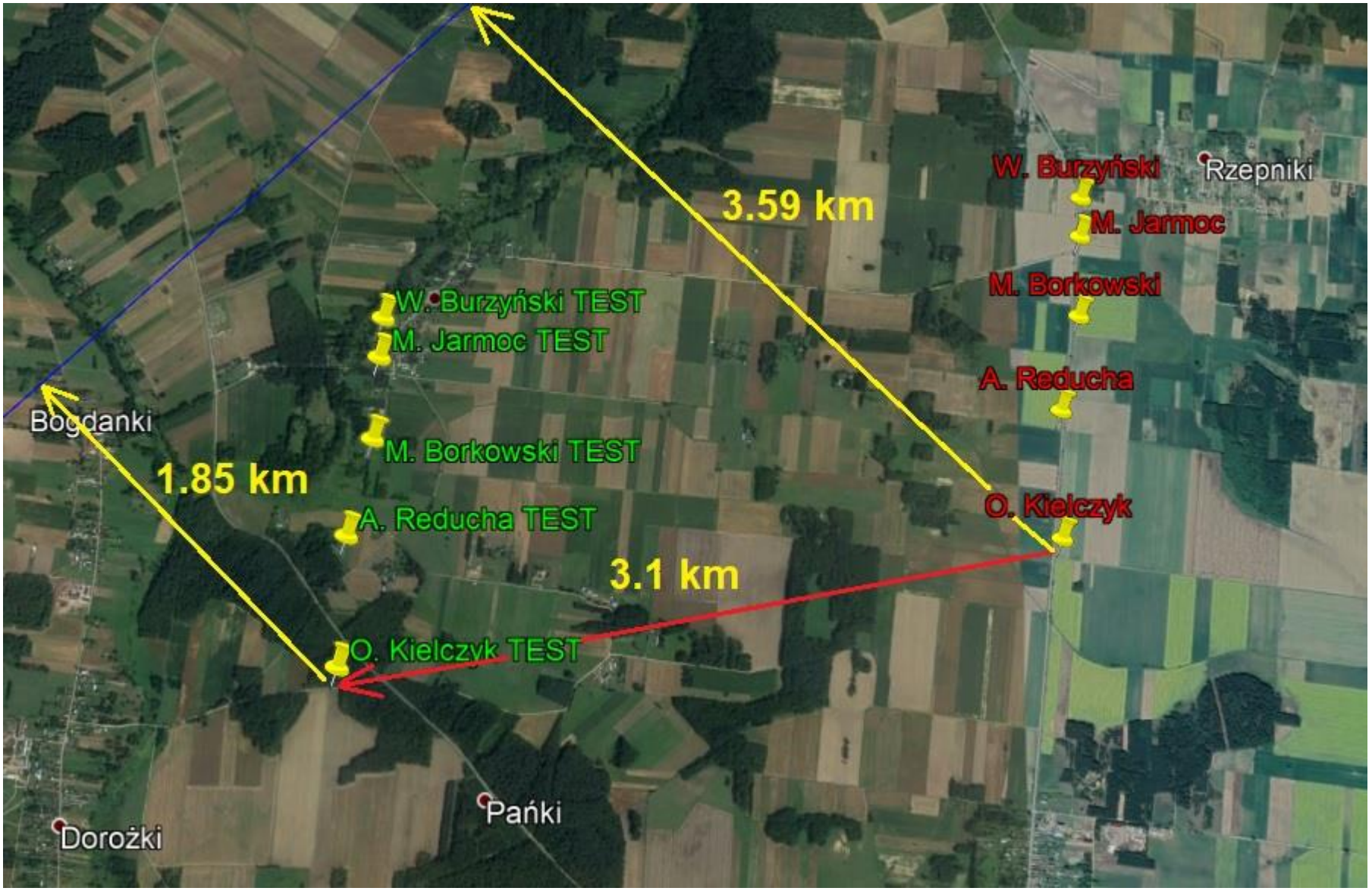
Rest of TEST STATIONS (trial and error)



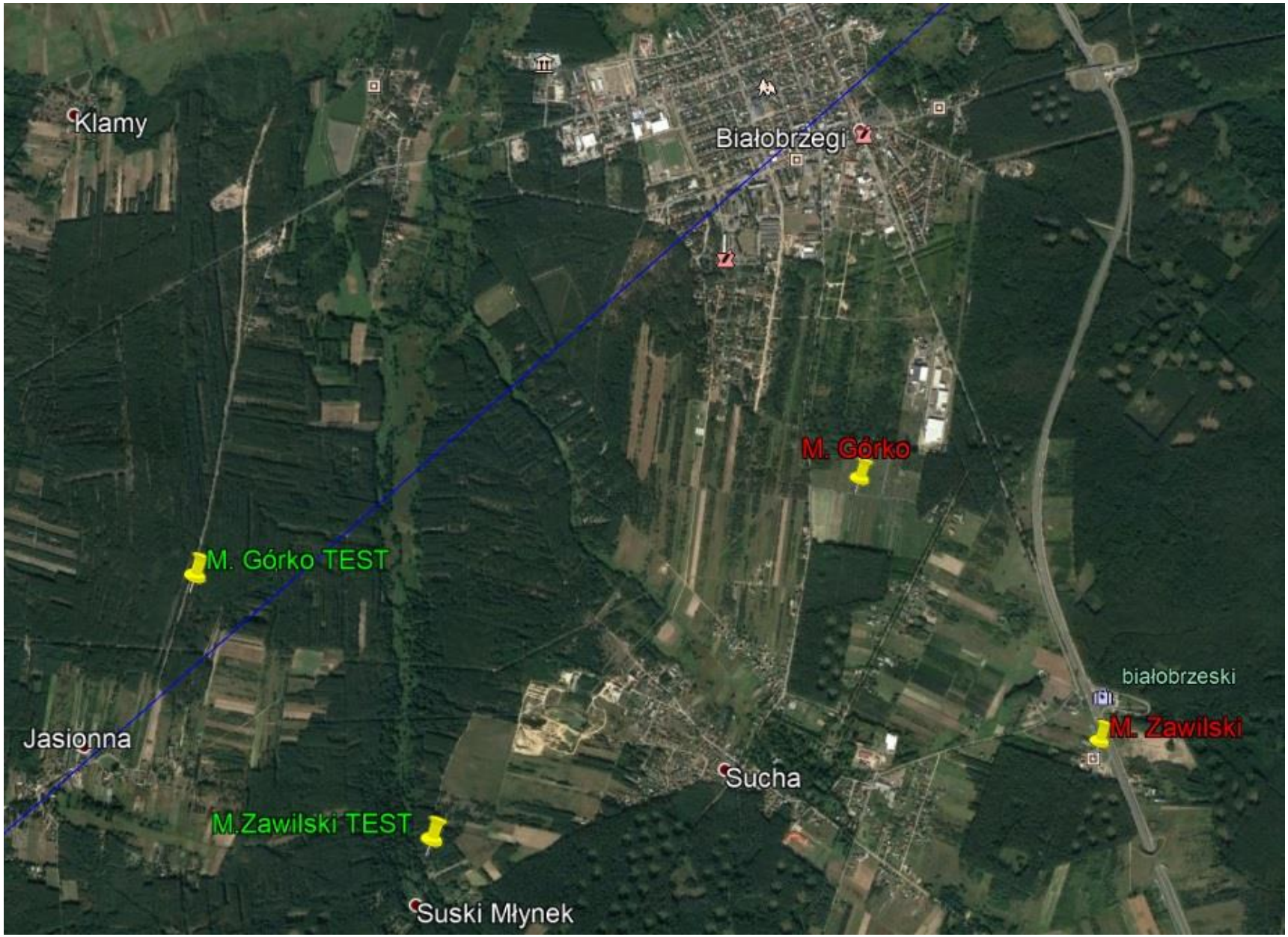
SHIFT
3.099 km

Azimuth
259.79

TEST STATIONS - Rzepniki (trial and error)



TEST STATIONS - Białobrzegi (trial and error)



TEST STATIONS - coordinates, distances

After calculating the TEST STATIONS coordinates and their distance from the graze limit line (Google Earth), the maximum value of the perpendicular profile shift to the SOUTH is 1.74 km

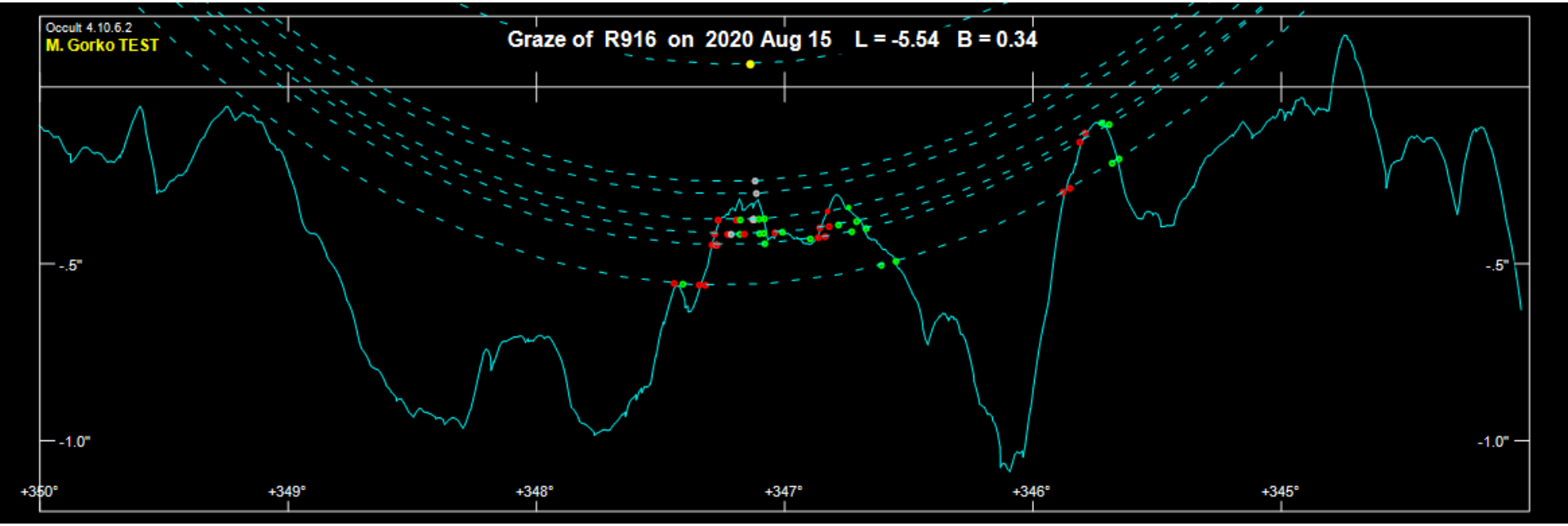
STN No	OBSERVER Name	LON WGS'84	LAT WGS'84	SHIFTED DIST.	
RZEPNIKI site - NE Poland					
1	Wojciech Burzynski	23 10 15.9	52 57 02.8	0.86 km	MISS
2	Maciej Jarmoc	23 10 15.4	52 56 57.1	0.98 km	MISS
Lunar profile begins at 1.13 km - slide no 10					
3	Maciej Borkowski	23 10 14.6	52 56 45.4	1.22 km	
4	Adam Reducha	23 10 09.7	52 56 31.8	1.47 km	
5	Oskar Kielczyk	23 10 09.0	52 56 13.8	1.85 km	
BIAŁOBRZEGI site - central Poland					
1	Marcin Gorko	20 54 46.1	51 37 34.6	-0.27 km	MISS
2	Marek Zawilski	20 55 45.2	51 36 56.6	1.37 km	

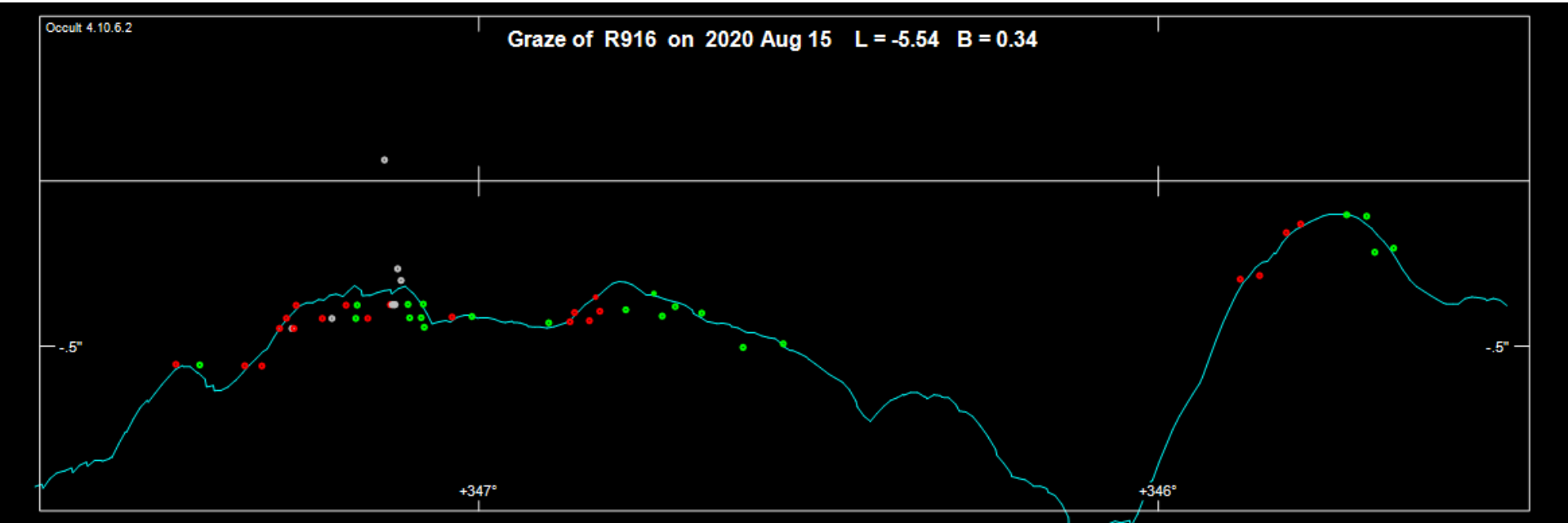
In this case lunar Vertical Profile Scale approx. 2.98 km/arcsec at mean distance of moon.

Summarizing the above, it should be understood that the star „has moved" perpendicular to the graze limit line by the value 0.584" north (or the Moon profile „has moved" perpendicular to the south)

... but 3.1 km distance between real and TEST STATION gives even 1.04"...

Overall results of TEST STATIONS - events





Overall results of TEST STATIONS – OC values

ref	Tel	Observer	Star	No.	y	m	d	h	m	s	PhGrMrCeDb	O-C mas	O-C sec	limb "
001	A	W. Burzynski TEST	R	916	2020	8	15	0	53	55	MD G G 1	+60	1.43	-0.33
002	B	M. Jarmoc TEST	R	916	2020	8	15	0	53	55	MD G G 1	+25	0.44	-0.33
003	C	M. Borkowski TEST	R	916	2020	8	15	0	53	50.15	DD G G 1 W	+20	-0.53	-0.39
004	C	M. Borkowski TEST	R	916	2020	8	15	0	53	52.31	DD G G 1 E	-40	-3.48	-0.33
005	C	M. Borkowski TEST	R	916	2020	8	15	0	53	52.79	RD G G 1 E	-59	-2.64	-0.32
006	C	M. Borkowski TEST	R	916	2020	8	15	0	53	54.23	DD G G 1 E	-45	-4.84	-0.33
007	C	M. Borkowski TEST	R	916	2020	8	15	0	53	54.31	FD G G 1 E	-45	-4.82	-0.33
008	C	M. Borkowski TEST	R	916	2020	8	15	0	53	54.39	BD G G 1 E	-44	-1.30	-0.33
009	C	M. Borkowski TEST	R	916	2020	8	15	0	53	54.43	FD G G 1 E	-44	-1.16	-0.33
010	C	M. Borkowski TEST	R	916	2020	8	15	0	53	54.99	RD G G 1 E	-54	-0.57	-0.32
011	C	M. Borkowski TEST	R	916	2020	8	15	0	53	55.65	RD G G 1 W	-6	-0.10	-0.37
012	C	M. Borkowski TEST	R	916	2020	8	15	0	54	3.11	DD G G 2 W	-5	0.12	-0.35
013	C	M. Borkowski TEST	R	916	2020	8	15	0	54	5.63	RD G G 2 W	+6	0.21	-0.35
014	D	A. Reducha TEST	R	916	2020	8	15	0	53	49.08	DD G G 1 W	-4	0.07	-0.44
015	D	A. Reducha TEST	R	916	2020	8	15	0	53	49.62	FD G G 1 W	-51	1.83	-0.39
016	D	A. Reducha TEST	R	916	2020	8	15	0	53	49.70	DD G G 1 E	-51	1.37	-0.39
017	D	A. Reducha TEST	R	916	2020	8	15	0	53	55.34	RD G G 1 E	-62	-1.41	-0.38
018	D	A. Reducha TEST	R	916	2020	8	15	0	54	0.73	RD G G 1 W	+16	-0.55	-0.44
019	D	A. Reducha TEST	R	916	2020	8	15	0	54	1.65	DD G G 1 W	-10	0.18	-0.42
020	D	A. Reducha TEST	R	916	2020	8	15	0	54	2.49	DD G G 1 E	-62	1.37	-0.36
021	D	A. Reducha TEST	R	916	2020	8	15	0	54	5.64	RD G G 1 E	-50	-2.14	-0.36
022	D	A. Reducha TEST	R	916	2020	8	15	0	54	7.35	RD G G 1 W	+12	0.51	-0.41
023	D	A. Reducha TEST	R	916	2020	8	15	0	54	32.67	DD G G 1 W	+6	-0.25	-0.16
024	D	A. Reducha TEST	R	916	2020	8	15	0	54	36.15	RD G G 1 W	+20	0.21	-0.13
025	E	O. Kielczyk TEST	R	916	2020	8	15	0	53	44.12	DD G G 1 W	+16	2.27	-0.57
026	E	O. Kielczyk TEST	R	916	2020	8	15	0	53	45.15	RD G G 1 W	+23	0.44	-0.58
027	E	O. Kielczyk TEST	R	916	2020	8	15	0	53	47.10	DD G G 1 W	+21	-0.27	-0.58
028	E	O. Kielczyk TEST	R	916	2020	8	15	0	53	47.84	DD G G 1 E	-43	0.43	-0.52
029	E	O. Kielczyk TEST	R	916	2020	8	15	0	54	8.66	RD G G 1 E	-47	-1.96	-0.46
030	E	O. Kielczyk TEST	R	916	2020	8	15	0	54	10.40	RD G G 1 W	+1	0.02	-0.49
031	E	O. Kielczyk TEST	R	916	2020	8	15	0	54	30.19	DD G G 1 W	+10	-0.21	-0.31
032	E	O. Kielczyk TEST	R	916	2020	8	15	0	54	31.03	DD G G 1 E	-40	0.88	-0.25
033	E	O. Kielczyk TEST	R	916	2020	8	15	0	54	36.02	RD G G 1 E	-72	-0.68	-0.14
034	E	O. Kielczyk TEST	R	916	2020	8	15	0	54	36.84	RD G G 1 W	+6	0.05	-0.21

Average OC value of 47 events (misses excluded):

0.026"

....but I still have no answer from M. Soma as to whether our observational data could be useful in any way ???

Unfortunately there is nothing in the XZ80Q catalogue that could sensibly be used to flag the possibility of this issue in future.

While the fact that the star is double can be retrieved, the fact that star position is based on Hipparcos is not available...

The solution - we will have to wait for Gais DR3, when the XZ80Q catalog can be comprehensively reworked to properly allow for orbital motions of double stars.

About 1 hour before the graze. Photography by Marcin Górko, Białobrzegi site

Thank you for your attention !

Recorded by Karol Wójcicki, Białobrzegi site