

IS NN DRACONIS A TRIPLE STAR?

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Abstract: We present the results of our observations of NN Draconis made over 14 nights from 2021 to 2026. We found a significant deviation in the O-C diagram compared to historical data. We compiled and analyzed all available measurements and compared them to our results. The updated O-C diagram shows a polynomial trend, possibly indicating a third component in the system. Continued observations are needed to refine the model.

1 Introduction

During telescope testing, NN Dra (NSV 6080, NSVS 2689370) was selected as a target. The star is an EW-type eclipsing binary at RA 13 04 02.97, DEC +65 15 24.29 (J2000). It varies in brightness from 12.34 to 12.98 mag in the Johnson *R* filter with a period of 0.382879 d, based on VARASTRO¹

2 Instrumentation and methodology

Our measurements were taken at Úpice Observatory in the Czech Republic.

- Telescope: Newtonian reflector 200/800 on a German equatorial mount,
- Camera: Moravian Instruments C2-7000, 12-bit, Sony IMX428 CMOS (3216 x 2208, 4.5 μm pixels),
- Filters: Johnson *BVRI*,
- Field of view: 62.2' x 42.7',
- Autoguiding: ASI camera.

All images were captured using SIPS². Differential photometry with dark frame and flat field correction was done in MUNIWIN³. The list of our observational nights, together with the photometric filters used, is shown in Table 1. Used comparison and check stars are selected in Figure 1, their parameters are listed in Table 2. Photometry was better than 0.06 mag RMS in all filters.

¹<https://var.astro.cz/cs>

²<https://www.gxccd.com/cat?id=23&lang=409>

³<https://c-munipack.sourceforge.net/>

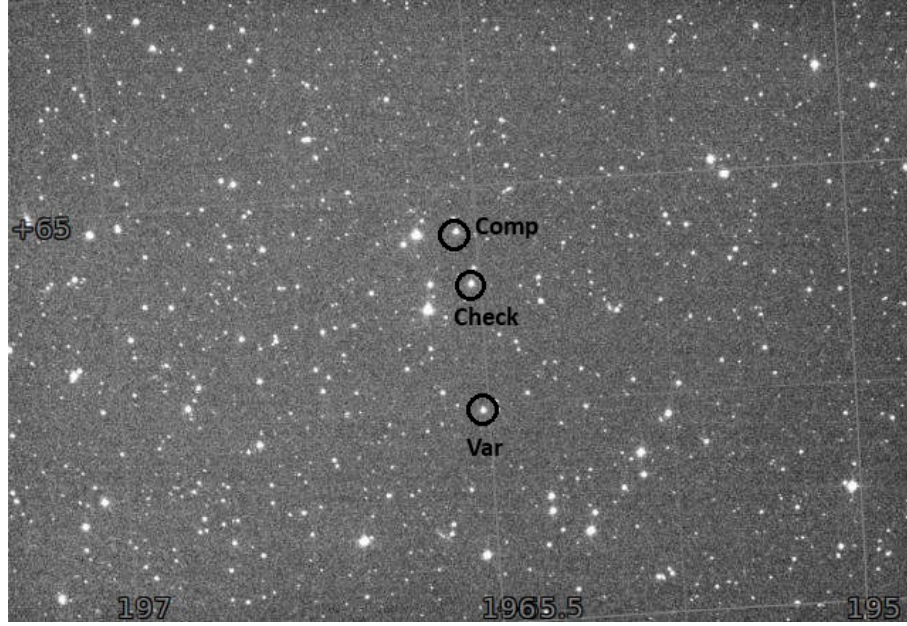


Figure 1: FOV with our stars in Draco.

Table 1: Observation log. Columns *B*, *V*, *R*, *I*, Clear give used exposure times in particular filters.

Night	Time-span [hours]	<i>B</i> [sec]	<i>V</i> [sec]	<i>R</i> [sec]	<i>I</i> [sec]	<i>C</i> [sec]
28/1 February, 2021	1.80	-	-	-	-	120
6/7 March, 2021	7.13	-	-	-	-	120
7/8 March, 2021	3.97	-	-	-	-	120
23/24 April, 2021	6.08	-	-	-	-	120
27/28 April, 2021	4.29	-	-	-	-	120
10/11 May, 2021	6.40	-	-	-	-	120
18/19 March, 2022	5.2	-	120	-	-	-
20/21 March, 2022	9.17	-	120	-	-	-
28/29 March, 2023	8.28	-	120	-	-	-
9/10 January, 2024	10.54	-	120	-	-	-
27/28 April, 2024	7.08	230	100	200	140	30
7/8 March, 2025	5.00	-	120	-	-	-
18/19 January, 2026	10.1	-	-	-	-	120
19/20 January, 2026	9.50	210	-	-	-	-
Total	94.54					

Table 2: Characteristics of comparison stars. Magnitudes are taken from Høg et al. (2000).

Star	ID	RA [h:m:s]	DEC [°:′:″]	<i>B</i> [mag]	<i>V</i> [mag]
Var	NN Dra	13:04:02.97	+65:15:24.28	12.34	12.30
Comp	2MASS J13041255+6503033	13:04:12.58	+65:03:03.41	13.38	12.50
Check	2MASS J13040521+6506415	13:04:05.20	+65:06:41.29	12.96	12.10

3 Data analysis

3.1 Data acquisition

We used PDR⁴ software and databases MAST⁵, AAVSO⁶, VIZIER⁷, and VarAstro to search for available measurements of NN Dra. Using PDR software, we located a few photometry points in KWS, SWASP, CRTS, IRSA, and APASS, and then reviewed the ASAS-SN⁸ survey. The AAVSO observations database contained only 3 minima for this star, which are already in the VarAstro database. We also examined data from the Spitzer Infrared Space Telescope, but the observations were too sparsely distributed in time to determine any minimum timings. We also searched ADS⁹ for previous papers and found only a few minima, already presented on VarAstro. On MAST, there were no data to fill the gap between 1999 and 2009, resulting in a long period without observations, but TESS data are available. This star was used as a guide star for the Hubble Space Telescope. We searched for additional data on Vizier and on STARGLASS¹⁰ catalogue of glass plates. Due to the inability to filter the data by RA and DEC, lack of information about the field of view, high exposure times, and relatively short period, we did not determine the timings of minima in data from Starglass catalogue. We also checked GAIA¹¹, but no timings of minima were determined from available Gaia photometric measurements due to the low cadence of data. All available sectors from TESS are listed in Table 3, all minima were determined by SILICUPS¹² using the minimum fit tool based on the method described in Mikulášek (2015). All determined minima from TESS dataset are in Table 8.

3.2 Data processing

From the obtained NN Dra data, only our own measurements, VarAstro database measurements, and TESS data were used for further analysis. After acquiring our own observations, we entered them into our observer database on VarAstro. We determined the timings of minima in our data using the method described in Brát, Mikulášek, and Pejcha (2012). We noticed that our first data point did not match previously published minima. As more nights of observation were added, we saw a steeper decline in the O-C diagram.

⁴<https://github.com/m-krajcovic/photometric-data-retriever>

⁵<https://archive.stsci.edu/>

⁶<https://www.aavso.org/>

⁷<https://vizier.cds.unistra.fr/>

⁸<https://asas-sn.osu.edu/>

⁹<https://ui.adsabs.harvard.edu/>

¹⁰<https://starglass.cfa.harvard.edu/>

¹¹<https://gea.esac.esa.int/archive/>

¹²<https://www.gxccd.com/cat?id=23&lang=409>

Table 3: List of all available TESS sectors.

Year	Sector number
2019	14
2019	15
2020	21
2020	22
2021	41
2022	48
2022	49
2024	75
2024	76

To check whether this discrepancy was due to errors in our data, we also analyzed TESS satellite data, which confirmed consistency with our results. All used ground-based observation minima are listed in Table 6. Timings of minima were determined only for minima with sufficiently covered descending and ascending branches. The change in period is shown in Figure 2.

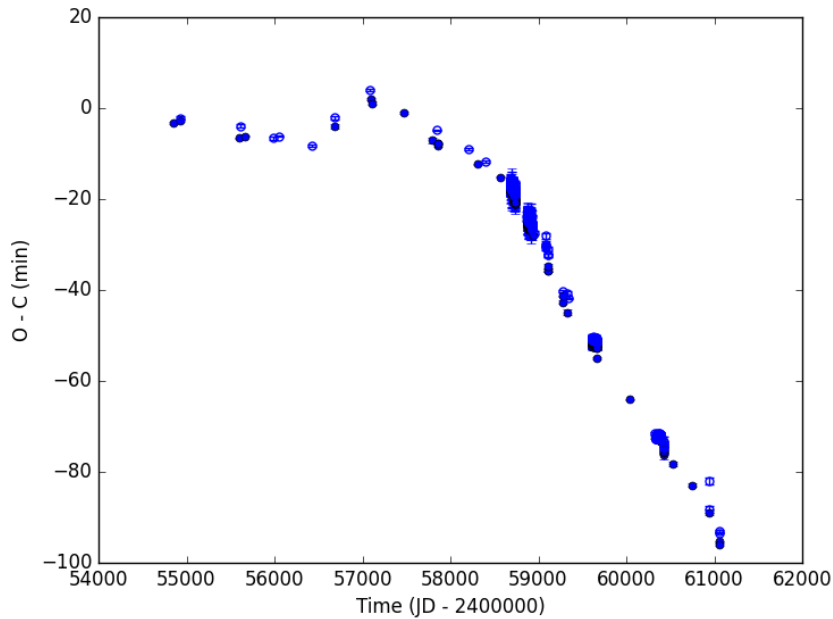


Figure 2: All used data points from VarAstro + TESS. The O-C diagram uses the old period 0.382879; full points are primary minima, and empty points are secondary minima.

For the first minimum on VarAstro the value of error is not listed, so it was excluded from further analysis. For the determination of the new period, we inserted the linear part of Figure 2 (from time 2458565 further) into OCFit Gajdoš and Parimucha (2019) and made a linear fit (see Figure 3). The TESS data, phased with the newly determined ephemerides from Table 4, are shown in Figure 5.

In the O-C diagram (see Figure 2), small changes are visible even in the linear part, which could be due to a potential third body. The model that best describes the system comprises mass transfer and the LITE (light-time effect) for the potential third body.

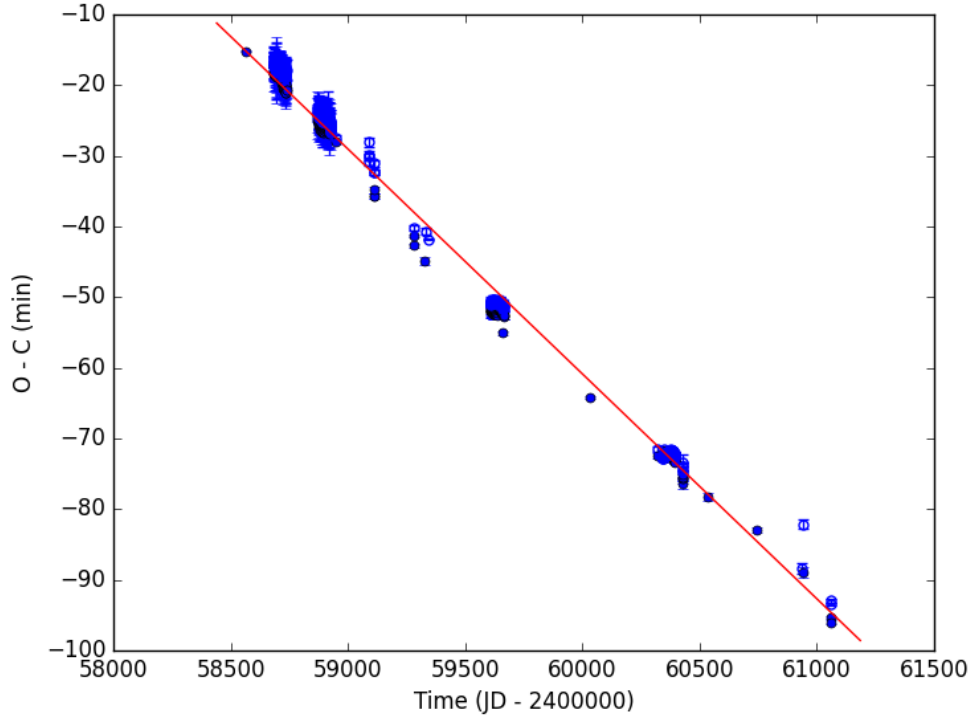


Figure 3: Fit of the linear part of O-C diagram.

Table 4: Comparison of period of system NN Dra.

	M_0 [HJD]	Period [d]
Old	2451285.6690	0.382879
New	2451285.8194(9)	0.38287054(4)

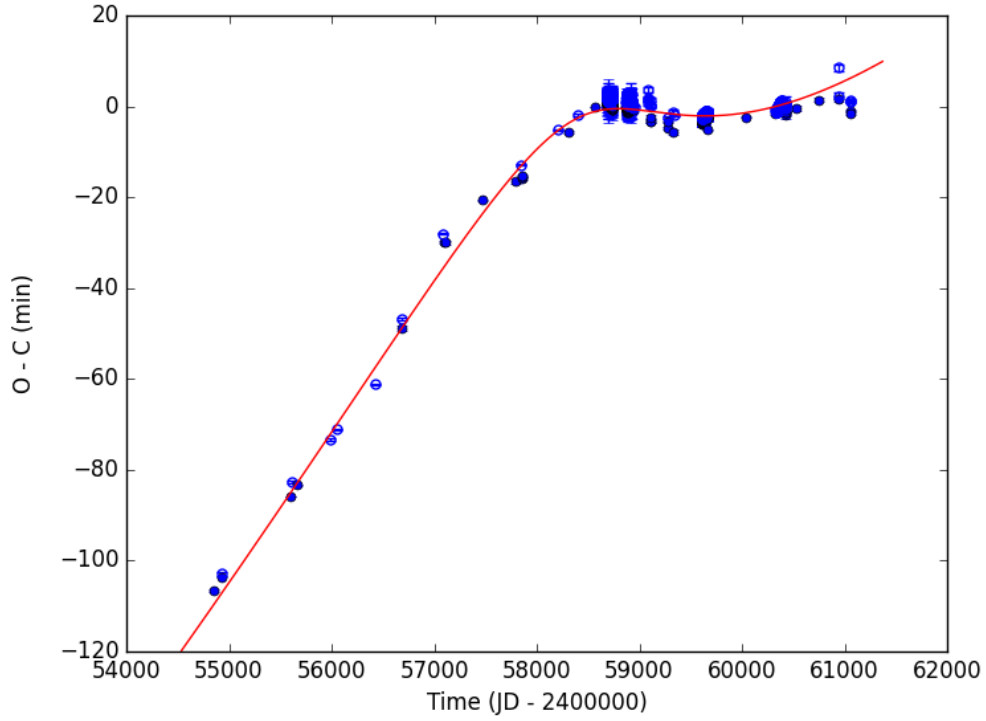


Figure 4: Model of the system in OCFit (new ephemerides from Table 4). Values of the model parameters are in Tables 5 and 6.

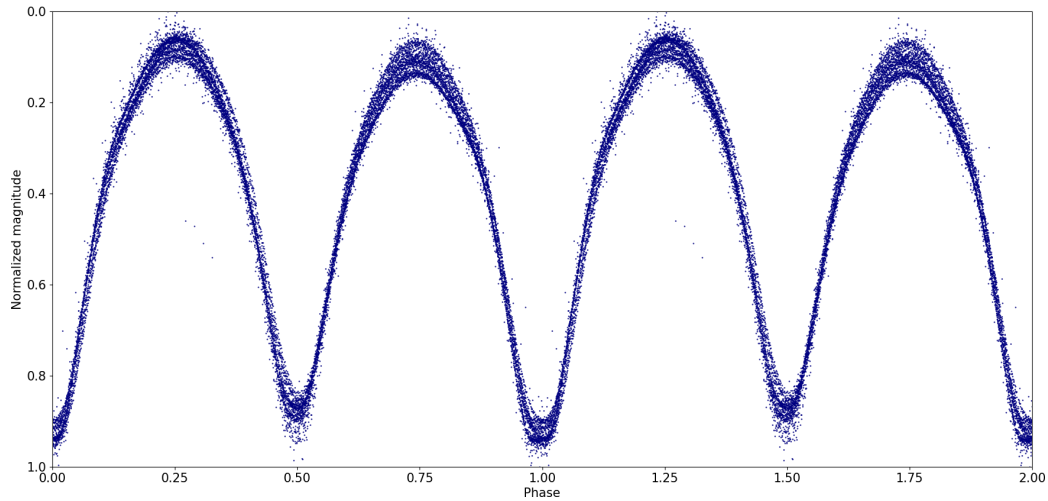


Figure 5: Phase curve with TESS data phased with new ephemerides (see Table 4).

4 Results

From the linear part of the O-C diagram, we determined the new value of the period. The new period is listed in Table 4. Using OCFit, we derived preliminary orbital parameters for a potential third component in the system and mass transfer:

- $a \sin i_3$: projected semi-major axis of the orbit along the line of sight,
- e_3 : orbital eccentricity,
- w_3 : argument of periastron,
- t_{03} , time of periastron passage,
- P_3 : orbital period,
- Q : quadratic term,
- K_3 semi-amplitude of the change on O-C diagram generated by LITE,
- f_{m3} mass function for the third companion.

The interpretation of the parameters was undertaken from Gajdoš and Parimucha (2019) and Davoudi et al. (2020).

These parameters are presented in Tables 5 and 6. The solution remains preliminary due to the limited time coverage and the long period of the potential third body. By subtracting the model from the data in Figure 4 the residua were obtained. In the residua, there are some changes, as you can see in Figure 6. Continued observations and a physical model in PHOEBE will be necessary to refine the model and confirm whether NN Dra is a three-star system.

Table 5: Orbital parameters of the model in Figure 4

$a \sin i_3$ [au]	e_3	w_3 [deg]	t_{03} [JD]	P_3 [d]	Q [d]
3.78(1)	0.55(1)	128.14(1)	2459030(10)	13200(10)	-1e-13(1)

Table 6: Mass transfer parameters of model in Figure 4.

K_3 [min]	f_{m3} [$M_\odot$]
29.5(4)	0.041(3)

4.1 Acknowledgements

We would like to thank the Variable Star and Exoplanet Section of the Czech Astronomical Society for organizing conferences that provide valuable opportunities for consultation with professional astronomers. We also thank Petr Zasche for his valuable assistance and helpful discussions.

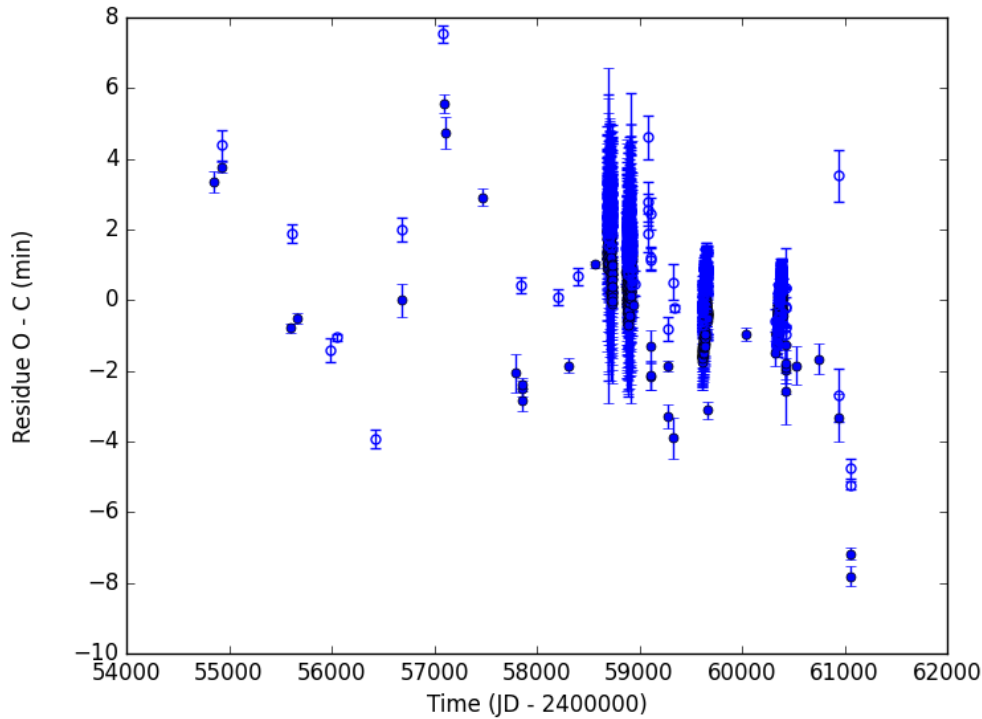


Figure 6: O-C diagram residuals (model subtracted from data) .

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L. Brát, Z. Mikulášek, and O. Pejcha. Minima timing of eclipsing binaries, 2012. URL <https://var.astro.cz/var-astro/doc/ebfit.pdf>.

Table 7: All used times of minima from VarAstro and our measurements.

Time of minima [HJD]	Author of measurements	Type of minima
2454847.5901	Raetz	Primary
2454924.3581	Agerer	Secondary
2454924.5491	Agerer	Primary
2455599.56213	Lehký	Primary
2455615.45348	Lehký	Secondary
2455670.39501	Polák	Primary
2455992.58741	Lehký	Secondary
2456050.40246	Scaggiante	Secondary
2456431.36552	Lehký	Secondary
2456683.49434	Lehký	Primary
2456683.68717	Lehký	Secondary
2457090.30878	Lehký	Secondary
2457090.49885	Lehký	Primary
2457115.38542	Jacobsen	Primary
2457473.37585	Jacobsen	Primary
2457798.43587	CCD Sekce Štefánikova hvězdárna	Primary
2457840.36267	Ehrenberger	Secondary
2457854.33544	Vrašťák	Primary
2457854.33566	Vrašťák	Primary
2457854.33574	Vrašťák	Primary
2458211.36958	Ehrenberger	Secondary
2458303.44961	Ehrenberger	Primary
2458404.33864	Ehrenberger	Secondary
2458565.33689	Holý	Primary
2458947.4412	Pokorný	Primary
2458948.39881	Pokorný	Secondary
2459087.38155	Ehrenberger	Secondary
2459087.38201	Ehrenberger	Secondary
2459087.38217	Ehrenberger	Secondary
2459087.38344	Ehrenberger	Secondary
2459110.35322	Ehrenberger	Secondary
2459110.35325	Ehrenberger	Secondary
2459110.35413	Ehrenberger	Secondary
2459110.54235	Ehrenberger	Primary

2459110.54237	Ehrenberger	Primary
2459110.54295	Ehrenberger	Primary
2459280.34603	Mrllák	Secondary
2459280.53576	Mrllák	Primary
2459281.30248	Mrllák	Primary
2459328.39406	Mrllák	Primary
2459332.41726	Mrllák	Secondary
2459345.43433	Mrllák	Secondary
2459657.47397	Mrllák	Secondary
2459659.38838	Mrllák	Secondary
2459659.57736	Mrllák	Primary
2460032.49523	Mrllák	Primary
2460319.45791	Mrllák	Secondary
2460319.6487	Mrllák	Primary
2460428.38366	Ulrich	Primary
2460428.38409	Ulrich	Primary
2460428.38414	Ulrich	Primary
2460428.3842	Ulrich	Primary
2460428.38457	Ulrich	Primary
2460428.57621	Ulrich	Secondary
2460428.57636	Ulrich	Secondary
2460428.57675	Ulrich	SecondaryS
2460428.57677	Ulrich	Secondary
2460428.57714	Ulrich	Secondary
2460534.43983	Školník	Primary
2460742.33984	Mrllák	Primary
2460937.41296	Jordanov	Secondary
2460938.36971	Jordanov	Primary
2460939.33165	Jordanov	Secondary
2461059.35501	Ulrich	Primary
2461059.54779	Ulrich	Secondary
2461060.31387	Ulrich	Secondary
2461060.50319	Ulrich	Primary

Table 8: All used time of minima determined in TESS dataset.

Time of minima [HJD]	error [HJD]	Type of minima
2458683.454421	0.000925	Secondary
2458683.644411	0.000504	Primary
2458683.836593	0.001309	Secondary
2458684.027351	0.000724	Primary
2458684.219906	0.000504	Secondary
2458684.410765	0.001303	Primary
2458684.602427	0.000885	Secondary
2458684.792855	0.001732	Primary
2458684.985455	0.000924	Secondary
2458685.176005	0.000190	Primary
2458685.368838	0.001028	Secondary
2458685.559247	0.000638	Primary
2458685.750841	0.001390	Secondary
2458685.941578	0.000795	Primary
2458686.134036	0.000867	Secondary
2458686.324819	0.001158	Primary
2458686.517373	0.000922	Secondary
2458686.707319	0.000493	Primary
2458686.899546	0.001090	Secondary
2458687.090291	0.000714	Primary
2458687.282811	0.000964	Secondary
2458687.473607	0.001258	Primary
2458687.855755	0.001021	Primary
2458688.048193	0.000820	Secondary
2458688.239050	0.000260	Primary
2458688.431535	0.000709	Secondary
2458688.622080	0.000588	Primary
2458688.813761	0.001047	Secondary
2458689.004564	0.001641	Primary
2458689.196806	0.000432	Secondary
2458689.387931	0.001749	Primary
2458689.579859	0.000366	Secondary
2458689.770251	0.000548	Primary
2458689.962212	0.000971	Secondary
2458690.153268	0.000396	Primary
2458690.345601	0.000553	Secondary
2458690.536503	0.001526	Primary

2458690.728069	0.000252	Secondary
2458690.918748	0.001460	Primary
2458691.110932	0.000547	Secondary
2458691.302087	0.000324	Primary
2458691.494260	0.000932	Secondary
2458691.684988	0.000717	Primary
2458691.876498	0.000856	Secondary
2458692.067414	0.002116	Primary
2458692.259562	0.000295	Secondary
2458692.450831	0.003287	Primary
2458692.642685	0.000842	Secondary
2458692.833207	0.000523	Primary
2458693.025084	0.001054	Secondary
2458693.216241	0.000436	Primary
2458693.408535	0.000576	Secondary
2458693.599706	0.002145	Primary
2458693.790851	0.000813	Secondary
2458693.981646	0.002058	Primary
2458694.173833	0.000595	Secondary
2458694.365092	0.000551	Primary
2458694.557306	0.000964	Secondary
2458694.747858	0.000365	Primary
2458694.939468	0.002814	Secondary
2458695.130716	0.001203	Primary
2458695.322753	0.000277	Secondary
2458695.514218	0.002294	Primary
2458695.705666	0.000544	Secondary
2458695.896131	0.001612	Primary
2458696.087910	0.001350	Secondary
2458696.279305	0.000211	Primary
2458697.428139	0.000617	Primary
2458697.620372	0.000922	Secondary
2458697.810855	0.000628	Primary
2458698.002645	0.000844	Secondary
2458698.193694	0.000497	Primary
2458698.385902	0.000429	Secondary
2458698.576987	0.001141	Primary
2458698.768682	0.000478	Secondary
2458698.959236	0.000902	Primary
2458699.151295	0.000752	Secondary

2458699.342363	0.000168	Primary
2458699.534770	0.000642	Secondary
2458699.725531	0.001146	Primary
2458699.916999	0.001110	Secondary
2458700.107717	0.001132	Primary
2458700.300119	0.000538	Secondary
2458700.491266	0.001417	Primary
2458700.683461	0.000953	Secondary
2458700.873691	0.000216	Primary
2458701.065810	0.001039	Secondary
2458701.256719	0.000590	Primary
2458701.449005	0.000996	Secondary
2458701.639514	0.000951	Primary
2458702.022397	0.001039	Primary
2458702.214455	0.000685	Secondary
2458702.405541	0.001144	Primary
2458702.597773	0.000644	Secondary
2458702.788619	0.000556	Primary
2458702.980110	0.000839	Secondary
2458703.171150	0.001170	Primary
2458703.363304	0.000470	Secondary
2458703.554598	0.001495	Primary
2458703.746352	0.001079	Secondary
2458703.936966	0.000470	Primary
2458704.128721	0.001407	Secondary
2458704.319848	0.000604	Primary
2458704.512028	0.000622	Secondary
2458704.703269	0.001429	Primary
2458704.894575	0.000622	Secondary
2458705.085387	0.001013	Primary
2458705.277258	0.000604	Secondary
2458705.468567	0.000206	Primary
2458705.660860	0.000784	Secondary
2458705.851882	0.000119	Primary
2458706.043069	0.001558	Secondary
2458706.234039	0.002322	Primary
2458706.426276	0.000429	Secondary
2458706.617470	0.001849	Primary
2458706.809425	0.000751	Secondary
2458706.999755	0.000540	Primary

2458707.191878	0.001053	Secondary
2458707.382715	0.000777	Primary
2458707.575199	0.000769	Secondary
2458707.766157	0.001671	Primary
2458707.957722	0.001049	Secondary
2458708.148216	0.002051	Primary
2458708.340675	0.000514	Secondary
2458708.531570	0.000500	Primary
2458708.724052	0.001012	Secondary
2458708.914305	0.001120	Primary
2458709.106134	0.001259	Secondary
2458709.296807	0.001805	Primary
2458709.489496	0.000623	Secondary
2458709.680733	0.001616	Primary
2458709.872381	0.000727	Secondary
2458710.062524	0.001529	Primary
2458711.594426	0.000628	Primary
2458711.787022	0.000853	Secondary
2458711.977193	0.000266	Primary
2458712.169218	0.001077	Secondary
2458712.360098	0.000814	Primary
2458712.552494	0.001262	Secondary
2458712.743383	0.001088	Primary
2458712.935236	0.000381	Secondary
2458713.125685	0.000834	Primary
2458713.317894	0.001209	Secondary
2458713.508848	0.000311	Primary
2458713.701103	0.000907	Secondary
2458713.891993	0.000887	Primary
2458714.083489	0.000817	Secondary
2458714.274224	0.001401	Primary
2458714.466594	0.000499	Secondary
2458714.657573	0.001720	Primary
2458714.849906	0.000544	Secondary
2458715.040008	0.000225	Primary
2458715.232056	0.001103	Secondary
2458715.422882	0.000979	Primary
2458715.806087	0.001953	Primary
2458715.998139	0.000329	Secondary
2458716.188228	0.000957	Primary

2458716.380834	0.000662	Secondary
2458716.571453	0.000139	Primary
2458716.764122	0.001040	Secondary
2458716.954687	0.000691	Primary
2458717.146484	0.001089	Secondary
2458717.336939	0.001822	Primary
2458717.529525	0.000631	Secondary
2458717.720360	0.001884	Primary
2458717.912862	0.000789	Secondary
2458718.102870	0.000487	Primary
2458718.294974	0.001051	Secondary
2458718.485562	0.000520	Primary
2458718.678387	0.000865	Secondary
2458718.868896	0.001316	Primary
2458719.251065	0.000970	Primary
2458719.443872	0.000688	Secondary
2458719.634320	0.000337	Primary
2458719.827023	0.000805	Secondary
2458720.017413	0.000518	Primary
2458720.209301	0.000791	Secondary
2458720.399722	0.002139	Primary
2458720.592326	0.000134	Secondary
2458720.783052	0.001152	Primary
2458720.975483	0.000700	Secondary
2458721.165454	0.000489	Primary
2458721.357868	0.001000	Secondary
2458721.548589	0.000411	Primary
2458721.741036	0.000555	Secondary
2458721.931745	0.001607	Primary
2458722.123473	0.000573	Secondary
2458722.313983	0.001237	Primary
2458722.506355	0.000547	Secondary
2458722.697218	0.000362	Primary
2458722.889771	0.000887	Secondary
2458723.080205	0.000510	Primary
2458723.271729	0.000609	Secondary
2458723.462482	0.001316	Primary
2458723.655135	0.000239	Secondary
2458725.186393	0.000777	Secondary
2458725.376605	0.001004	Primary

2458725.569441	0.000589	Secondary
2458725.759920	0.000501	Primary
2458726.143041	0.000579	Primary
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2458726.525262	0.000936	Primary
2458726.718249	0.000566	Secondary
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2458727.291002	0.000546	Primary
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