

Post-impact Mutual Orbit of the Didymos Binary System Derived from Photometry

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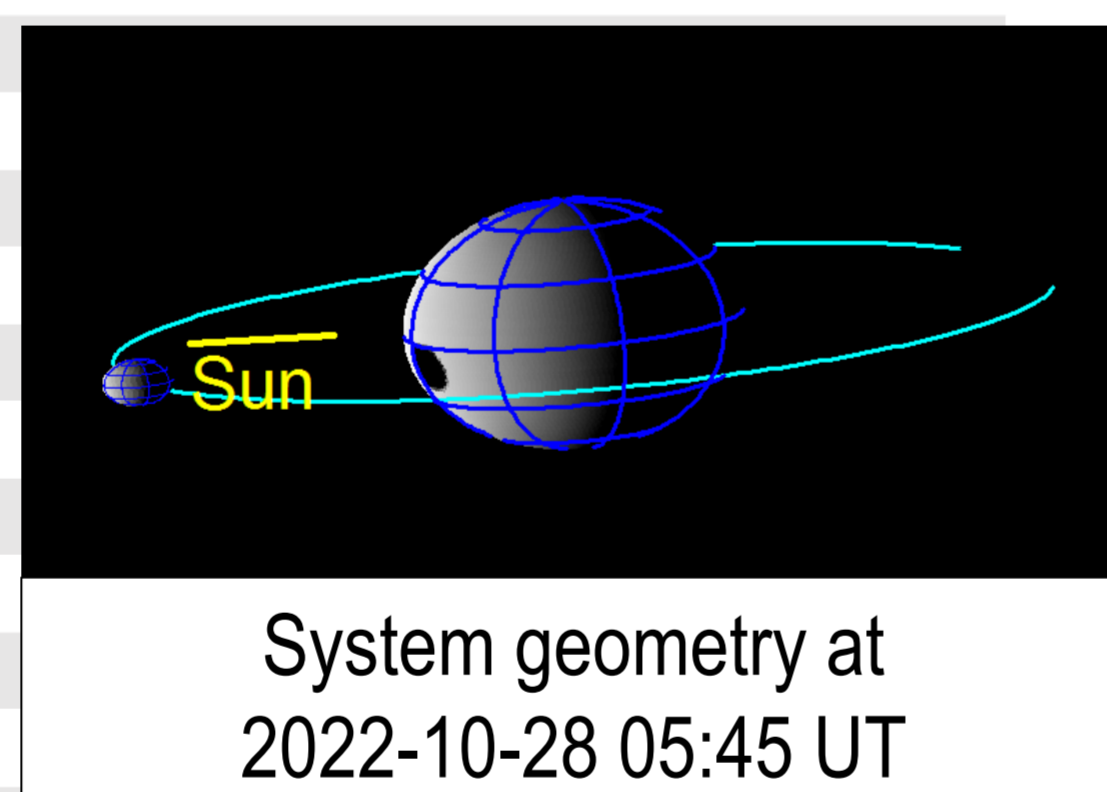
Introduction

On September 26, 2022, NASA's Double Asteroid Redirection Test (DART) spacecraft impacted the satellite, called Dimorphos, of the binary near-Earth asteroid (65803) Didymos. Thorough ground-based photometric observations of the Didymos system were scheduled from the impact through March 2023 in order to detect the orbit period change, its eccentricity and apsidal precession rate, as well as possible libration-induced orbit period variations (Meyer et al., 2021).

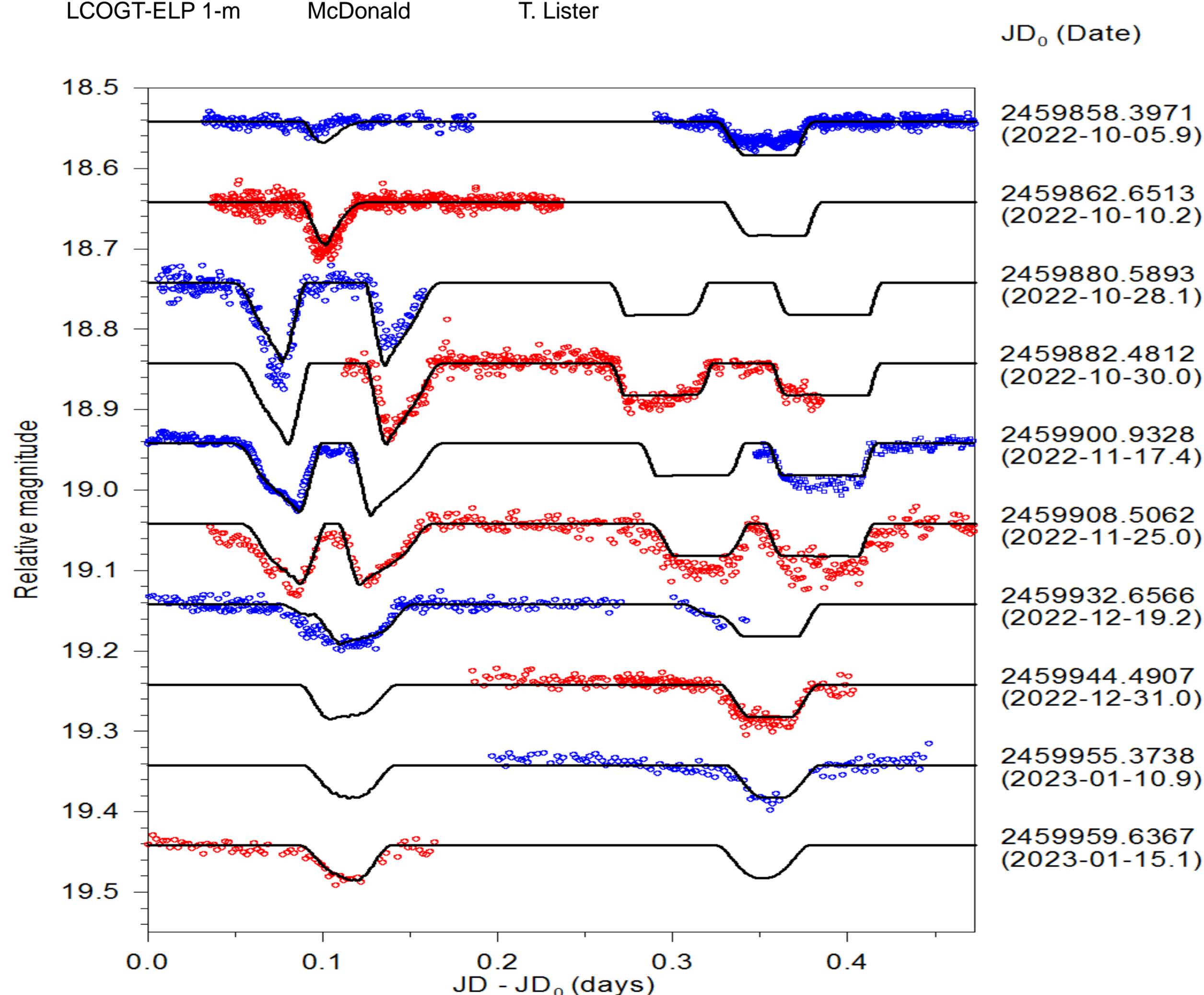
We present results of our modeling of the data. The model of the Didymos binary system was constructed adapting the technique described in Scheirich and Pravec (2022). The components were assumed to have ellipsoidal shapes and to be on Keplerian orbit, allowing for apsidal precession. Didymos and Dimorphos are assumed to be in a principal rotation state, with their pole orientations equal to the orbital pole. We fixed the orbital pole coordinates at their nominal values obtained for the pre-impact orbit by Scheirich and Pravec (2022), and ellipsoid axes, size ratios of the components and the semimajor axis at the values from Daly et al. (accepted in Nature).

Post-impact photometry data:

No. of nights	Telescope	Observatory	Observers/Reducers
L0 lunation (2022-09-28.2 to 2022-10-10.3):			
13	Danish 1.54-m	La Silla	C. Snodgrass/P. Pravec & coll.
10	LCOGT-LSC 1-m	CTIO	T. Lister
8	Swope 1-m	Las Campanas	D. Osip & coll.
6	LCOGT-CPT 1-m	SAAO	T. Lister
2	Lowell 1.1-m	Lowell	N. Moskovitz & coll.
L1 lunation (2022-10-28.1 to 2022-11-02.5):			
4	Danish 1.54-m	La Silla	P. Pravec & coll.
2	Ondřejov 0.65-m	Ondřejov	P. Pravec & coll.
2	LCOGT-TFN 1-m	Tenerife	T. Lister
1	VATT 1.8-m	Mt. Graham	J.-B. Kikwaya & C. Hergenrother
1	Spacewatch 0.9-m	Kitt Peak	J. Scotti, J. Larsen, M. Knight
L2 lunation (2022-11-17.4 to 2022-12-02.3):			
12	Lowell 1.1-m	Lowell	N. Moskovitz, T. Polakis, B. Skiff
9	Danish 1.54-m	La Silla	P. Pravec & coll.
6	Spacewatch 0.9-m	Kitt Peak	A. Tubbiolo, J. Larsen, M. Knight, M. Brucker, R. Mastaler & coll.
5	LCOGT-TFN 1-m	Tenerife	T. Lister
3	TRAPPIST-N 0.6-m		E. Jehin & M. Ferrais
3	MRO 2.4-m	Magdalena Ridge	B. Ryan & E. Ryan
2	LDT 4.3-m	Happy Jack	N. Moskovitz, C. Thomas, M. Knight
1	Maidanak 1.5-m	Maidanak	O. Burkhonov/P. Pravec & coll.
1	Stará Lesná 0.6-m	High Tatras	M. Husárik
1	Ondřejov 0.65-m	Ondřejov	P. Pravec & coll.
1	LCOGT-ELP 1-m	McDonald	T. Lister
1	Sugarloaf Mt. 0.64-m	Sugarloaf Mt.	D. Pray
L3 lunation (2022-12-17.1 to 2022-12-31.3):			
7	Danish 1.54-m	La Silla	P. Pravec & coll.
6	Lowell 1.1-m	Lowell	N. Moskovitz & T. Polakis
2	Sugarloaf Mt. 0.64-m	Sugarloaf Mt.	D. Pray
1	LCOGT-TFN 1-m	Tenerife	T. Lister
1	BOAO 1.8-m	BOAO	H.-J. Lee & coll.
1	MRO 2.4-m	Magdalena Ridge	B. Ryan & E. Ryan
1	Ondřejov 0.65-m	Ondřejov	P. Pravec & coll.
1	LCOGT-ELP 1-m	McDonald	T. Lister
L4 lunation (2023-01-11.2 to 2023-01-29.2):			
6	Danish 1.54-m	La Silla	P. Pravec & coll.
2	LCOGT-ELP 1-m	McDonald	T. Lister



System geometry at 2022-10-28 05:45 UT



Examples of the orbital lightcurve component of the data (points) and the synthetic lightcurve for the best-fit solution (solid curve).

Fixed parameters:

$A_1/C_1 = B_1/C_1 = 1.37$ Didymos and Dimorphos axes ratios

$A_2/C_2 = 1.53$

$B_2/C_2 = 1.50$

Didymos and Dimorphos are assumed to be in a principal rotation state, with their pole orientations equal to the orbital pole.

$A_2/A_1 = 0.208$ Dimorphos to Didymos size ratio

$a/A_1 = 1.3882$ Semimajor axis to Didymos size ratio
(All values above derived from Daly et al., accepted in Nature)

$L_p = 320.6^\circ$; $B_p = -78.6^\circ$ Orbital pole in ecliptic coordinates
(Pre-impact orbit; Scheirich and Pravec, 2022)

As the uncertainties of the fixed parameters have only insignificant effects, they were not considered.

Varied parameters:

ω_0 Argument of periapsis at t_{imp}

$P_{\text{orb}} = 2\pi/(n + d\omega/dt)$ Mean orbital period in inertial frame

e Eccentricity

$d\omega/dt$ Apsidal precession rate

$L_0 = \omega_0 + M_0$ Argument of mean length at t_{imp}

Best-fit solution:

P_{orb} (h)	e	$d\omega/dt$ ($^\circ/\text{day}$)	ω_0 ($^\circ$)	L_0 ($^\circ$)	$M_0 (=L_0 - \omega_0)$
11.3676	0.021	7.5	324	178	214
± 0.0014	± 0.014	± 1.0	± 50	± 5	± 45

(formal 3σ uncertainties)

Does an eccentricity damping occur in the system?

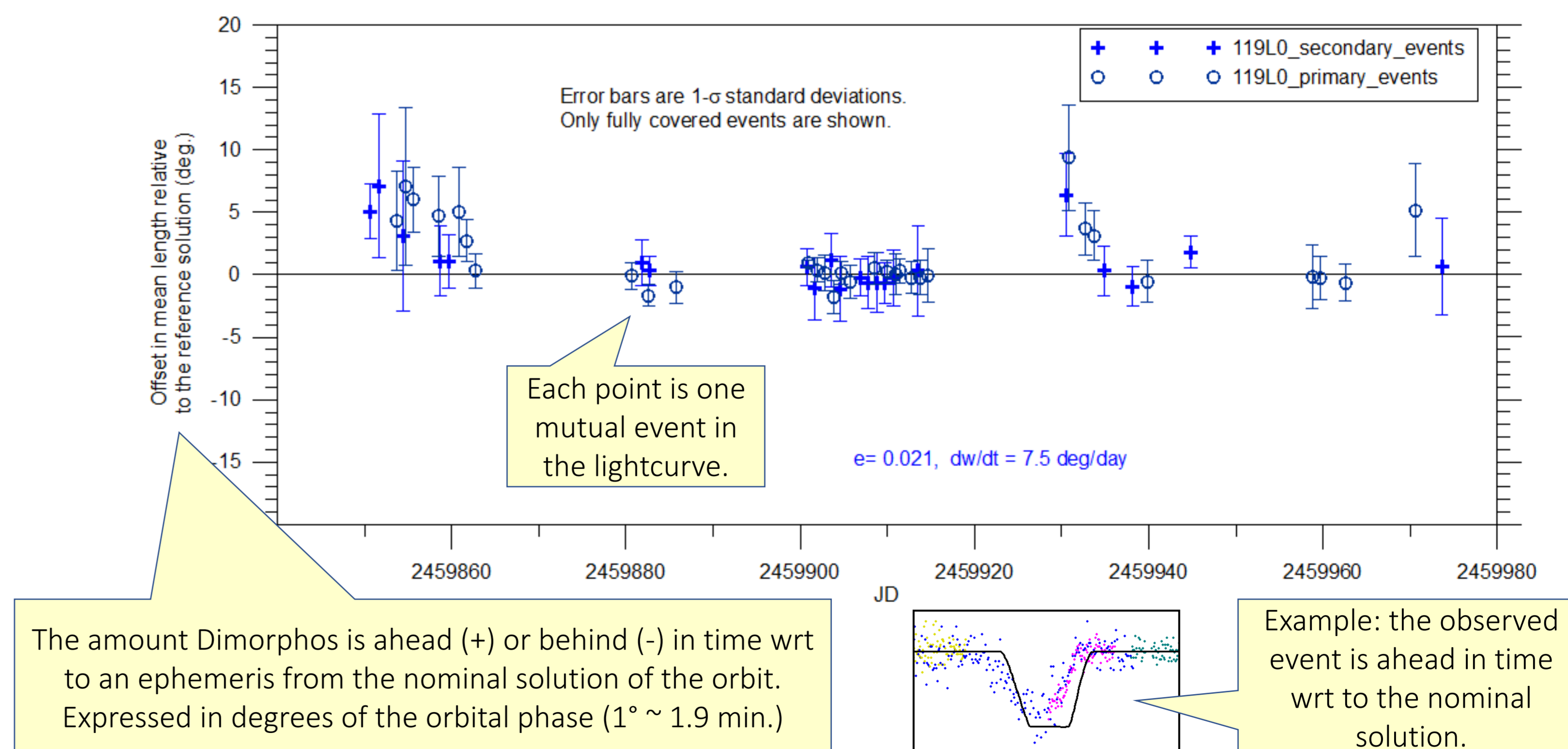
We also fitted two blocks of data separately: the first one with the data from L0 to L2 lunation and the second one with the data from L3 to L4 lunation, with the following results, indicating that the eccentricity is decreasing in the post-impact data.

Dataset	Time span	e
L0+L1+L2	2022-09-28 to 2022-12-02	0.024 ± 0.014
L3+L4	2022-12-17 to 2023-01-29	$0.014^{+0.020}_{-0.014}$

(formal 3σ uncertainties)

Do we see the orbit period oscillations?

In order to check for possible orbit period oscillations, we constructed the following figure, showing offsets in mean length for every observed mutual event with respect to the best-fit solution. As is apparent from the figure, we see some trends in the offset, but the results are not conclusive.



References

Meyer et al., 2021, Planetary Science Journal 2, 242

Scheirich and Pravec, 2022, Planetary Science Journal 3, 163