Results from modeling of photometric data of Didymos (2003 – 2021)

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In this modeling, we have used following data (added to all previous data from apparitions 2003 – 2019) from the current apparition (dataset called 2021 final):

2020-12-12.6 Gemini N
2020-12-17.4 LDT
2020-12-20.5 LDT
2020-12-23.4 LDT
2021-01-08.5 LDT
2021-01-09.4 LDT
2021-01-10.4 LDT
2021-01-12.6 Gemini N
2021-01-14.4 LDT
2021-01-14.6 Keck R
2021-01-17.5 Gemini N
2021-01-18.4 LBT
2021-01-20.2 TNG
2021-02-17.4 LDT
2021-03-06.3 LDT

For the complete 2003-2021 dataset see our prepared paper *Photometric observations of the binary near-Earth asteroid (65803) Didymos in 2015-2021 in support of the DART space mission*, draft available at http://www.asu.cas.cz/~asteroid/Didymos_observations_2015to2021_draft.pdf

The model of Didymos binary system was constructed using the technique described in Scheirich and Pravec (2009) and Scheirich et al. (2021). The components were assumed to be on a circular orbit and we allowed for a quadratic drift in mean anomaly, ΔM_d, fitted as a free parameter. ΔM_d is a coefficient in the second term of the expansion of the time-variable mean anomaly

$$M(t) = M(t_0) + n(t - t_0) + \Delta M_d(t - t_0)^2,$$

where

$$\Delta M_d = \frac{1}{2}\dot{n},$$

where n is the mean motion, t is time and t_0 is the epoch.

Best-fit parameters

Table 1 summarizes the best-fit model parameters of the binary system.
L_P, B_P are the ecliptic coordinates of the orbital pole in the equinox J2000, M_0 is the mean anomaly of the secondary, measured from the ascending node (as pericenter is not defined for circular orbit) for epoch t_0 = JD 2455873.0 (asterocentric UTC, i.e., LT-corrected), P_{orb} is the orbital period of the secondary, and ΔM_d is the quadratic drift in mean anomaly. Since the orbital period changes in time, the value presented in the table is valid for epoch t_0. For this epoch, which is approximately the mean time of all observed mutual events, a correlation between P_{orb} and ΔM_d is zero. We also give the time derivative of the mean motion, derived from ΔM_d. All reported uncertainties correspond to 3σ. We also report a 3σ uncertainty of the mean anomaly of the secondary at the time of the DART impact (2022-09-30) ΔM_{IMPACT}, derived from the uncertainties of the other parameters.

Table 1

Parameter	Value
L_P (deg.)	320.6 ± 13.7 [1]
B_P (deg.)	-78.6 ± 1.8
ΔM_d (deg/yr^2)	0.15 ± 0.14
$\dot{n}$ (rad/s^2)	5.26 ± 4.91 . 10^{-18}
P_{orb} (h)	11.921624 ± 0.000018
M_0 (deg.)	89.1 ± 4
t_0	JD 2455873.0 [2]
ΔM_{IMPACT} (deg.)	± 10

[1] For the actual shape of the uncertainty area, see Fig. 1. Semiaxes of the area are 1.8 x 3.0 deg.
[2] Asterocentric UTC, i.e. LT corrected.

Statistical significance of the solution for ΔM_d

The residuals of the model fitted to the observational data do not obey the Gaussian statistics because of systematic errors resulting from model simplifications. In particular, the residuals of nearby measurements appear correlated.

The uncertainties of the fitted parameters presented in Table 1 were estimated using the procedure described in Scheirich and Pravec (2009) and they are based on a visual comparison between model lightcurves and the data.

To eliminate the subjective uncertainties and the correlation between nearby measurements, we used a procedure described in Scheirich et al. (2021) for evaluating the statistical significance, based on the χ^2 test, of the solutions for ΔM_d.

Plot of the normalized χ^2 vs. ΔM_d are shown in Fig. 2.

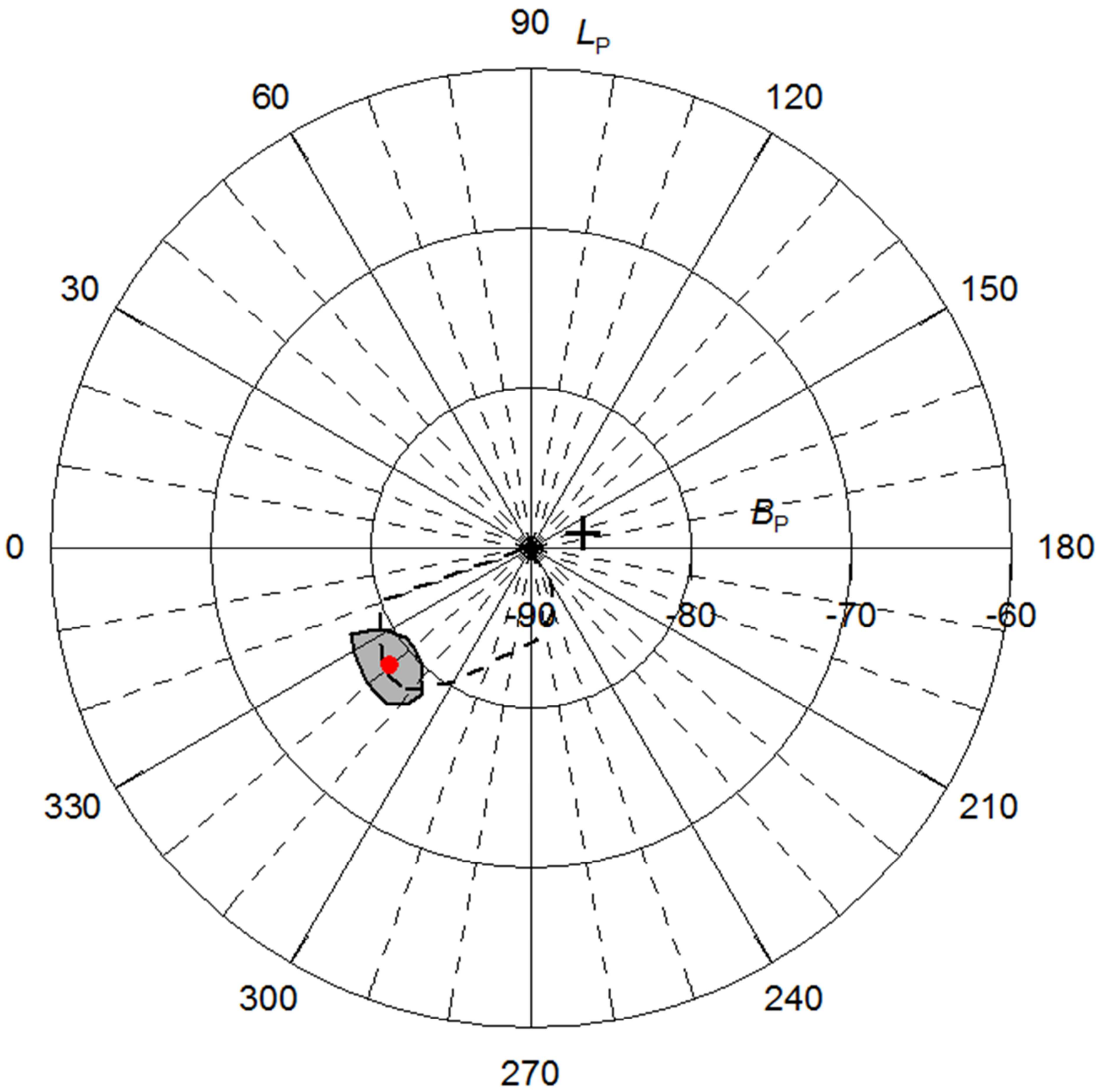

Figure 1. Area of admissible poles of the mutual orbit in ecliptic coordinates (grey area). The dot is the nominal solution given in Table 1. This area corresponds to 3σ confidence level. The dashed outline is the area of admissible poles derived from the data from the previous apparitions 2003 – 2019. Note that the current area is not fully within the area from the earlier model. This is because before we used a coarser grid for calculating the admissible uncertainty area. The south pole of the current asteroid's heliocentric orbit is marked with the cross.

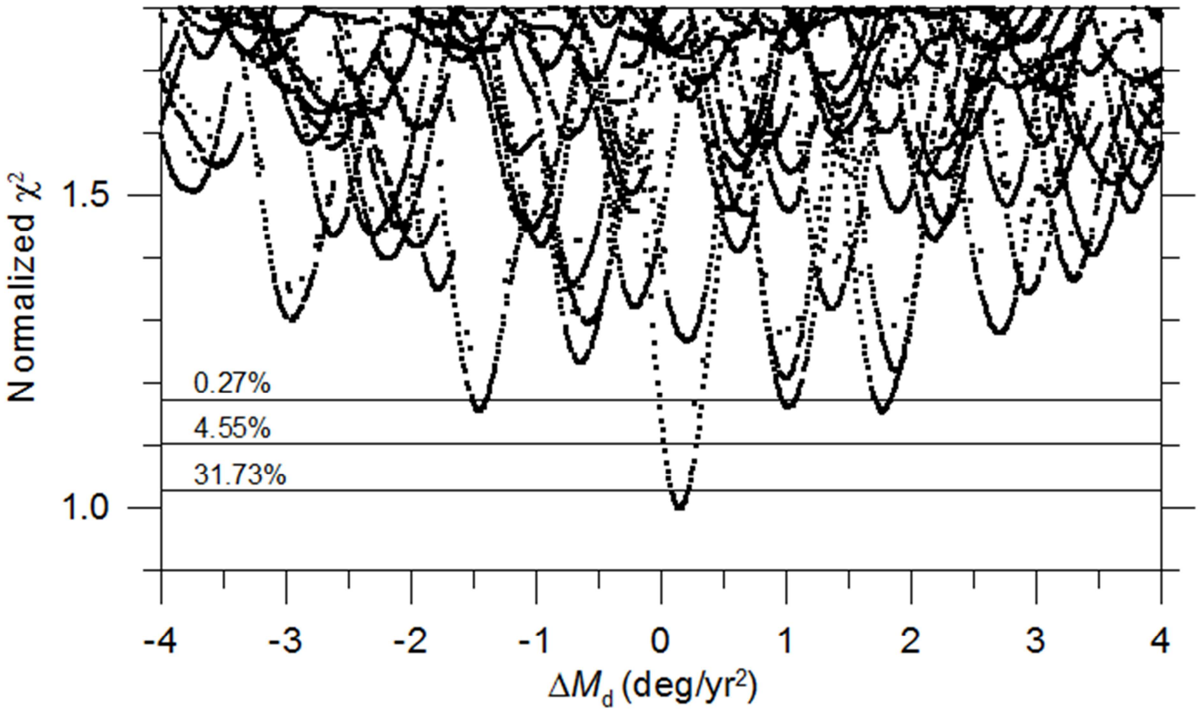

Figure 2. The normalized χ^2 vs. ΔM_d. The three horizontal lines gives the p-values – the probabilities that the χ^2 exceeds a particular value only by chance, corresponding to 1-, 2- and 3σ interval of the χ^2 distribution.

References

Scheirich, P., Pravec, P., 2009. Modeling of lightcurves of binary asteroids. Icarus, 200, 531–547.
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