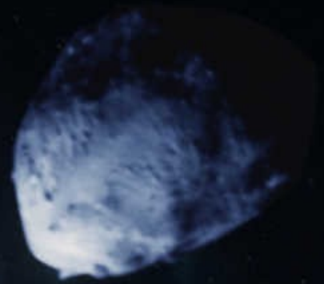

DART

NASA

Determination of Dimorphos's change in velocity resulting from the DART kinetic impact

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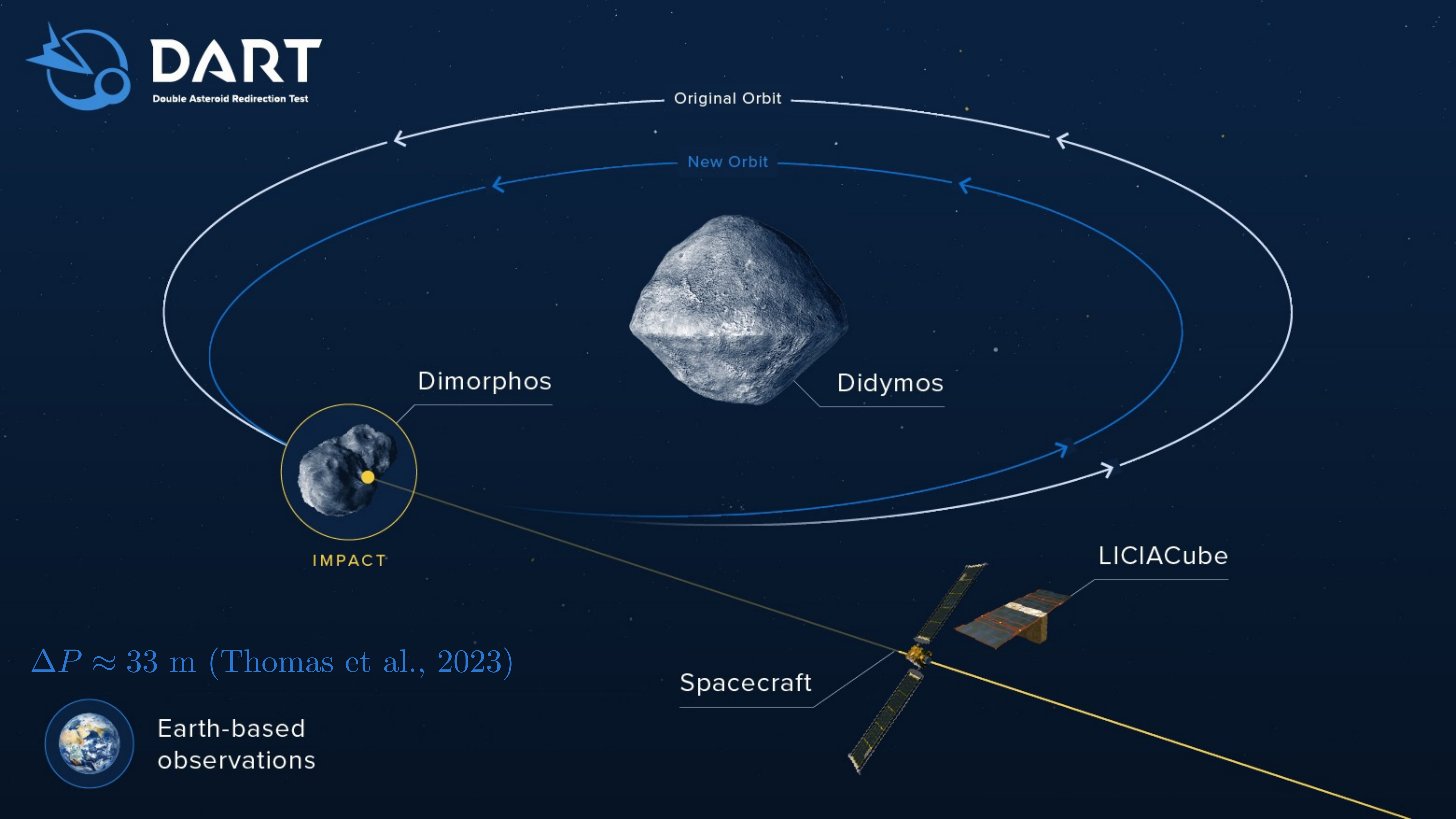
Cheng, A.F. et al., *Nature*, doi: 10.1038/s41586-023-05878-z



$\Delta P \approx 33$ m (Thomas et al., 2023)

In an idealized 1D world…

$$\frac{\Delta v}{v} = \frac{\Delta P}{3P}$$

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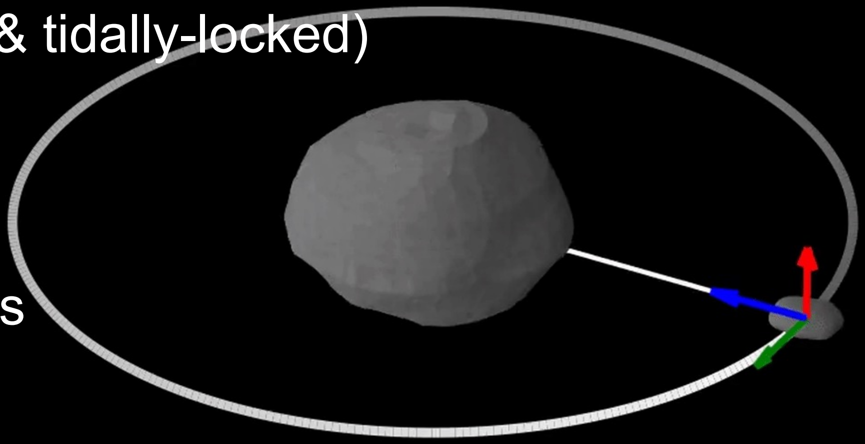
Additionally, the calculation of β must account for 3D impact geometry. (See next talk)

What does ΔP measure?

The change in orbit period is only sensitive to Δv_T, the "along-track" change in orbital velocity

Due to non-Keplerian dynamics & spin-orbit coupling, we use a Full Two-body Problem (F2BP) code to determine Δv_T from ΔP:

- General Use Binary Asteroid Simulator (GUBAS, Davis & Scheeres 2020)
- Assume dynamically-relaxed pre-impact state (circular orbit & tidally-locked)
- Neglect mass loss, time-dependent momentum transfer, etc.
- Rigid body dynamics evolved under 2^{nd}-order mutual gravity
- Didymos and Dimorphos treated as uniform density ellipsoids



Determining Δv_T: Monte Carlo approach coupled to F2BP simulations

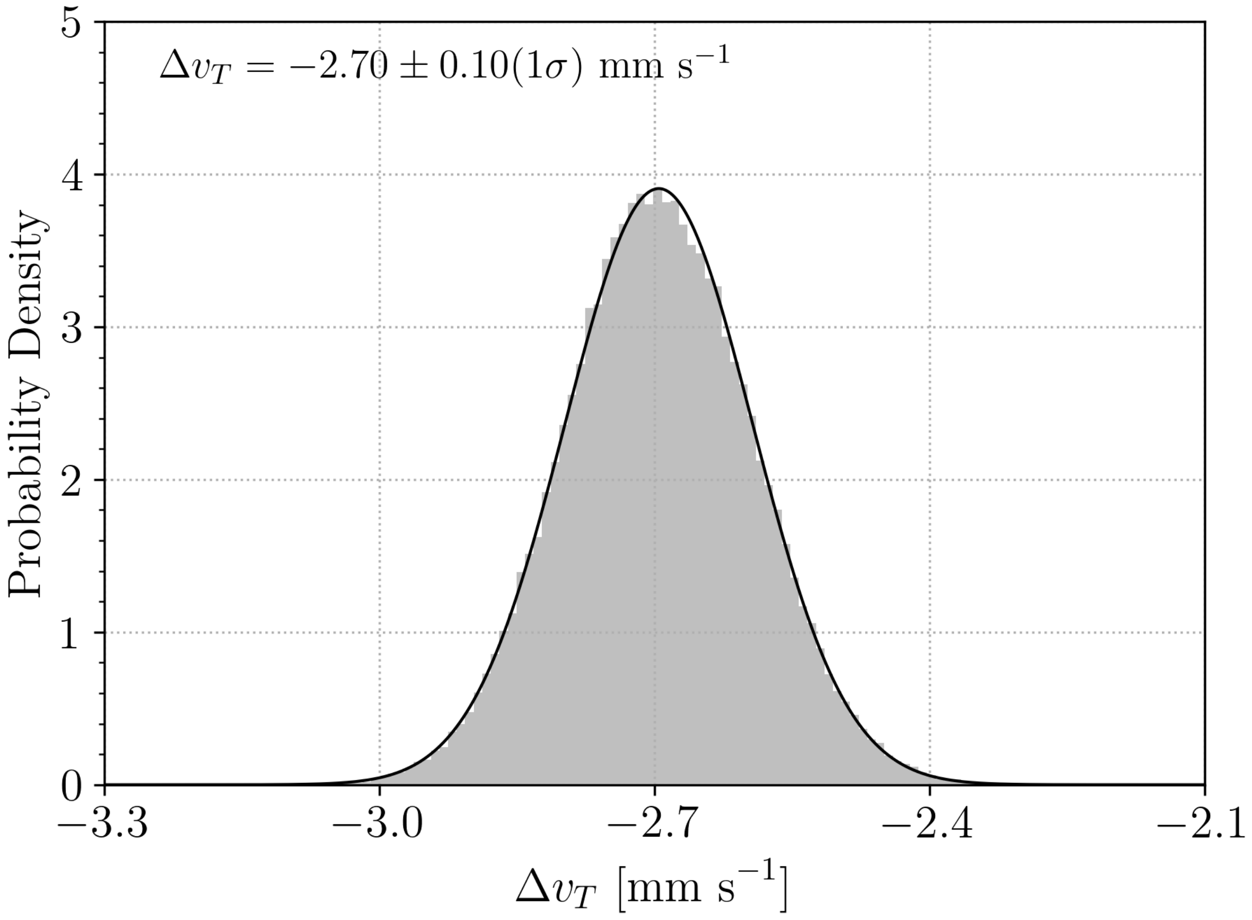
Need to account for uncertainties in pre- and post-impact state of Didymos system

1. Sample pre-impact system with uncertainties
2. Numerically determine the required mass of primary required to achieve sampled pre-impact state
3. Numerically determine required Δv_T to achieve sampled post-impact orbit period
4. Repeat ~100,000 times

Parameter	Value (1σ)	Note
Didymos extents (x,y,z) [h]	851 ± 15, 849 ± 15, 620 ± 15	Sampled uniformly
Dimorphos extents (x,y,z) [m]	177 ± 2, 174 ± 4, 116 ± 2	Sampled uniformly
Dimorphos density [kg/m^3]	2400 ± 300	Sampled uniformly to 3σ
Pre-impact semimajor axis [m]	1206 ± 35	Gaussian
Pre-impact orbit period [h]	11.92148 ± 0.000044	Gaussian
Post-impact orbit period [h]	11.372 ± 0.0055	Gaussian

Determination of Δv_T

$$\Delta v_T = -2.7 \pm 0.1(1\sigma)\ \mathrm{mm\ s^{-1}}$$

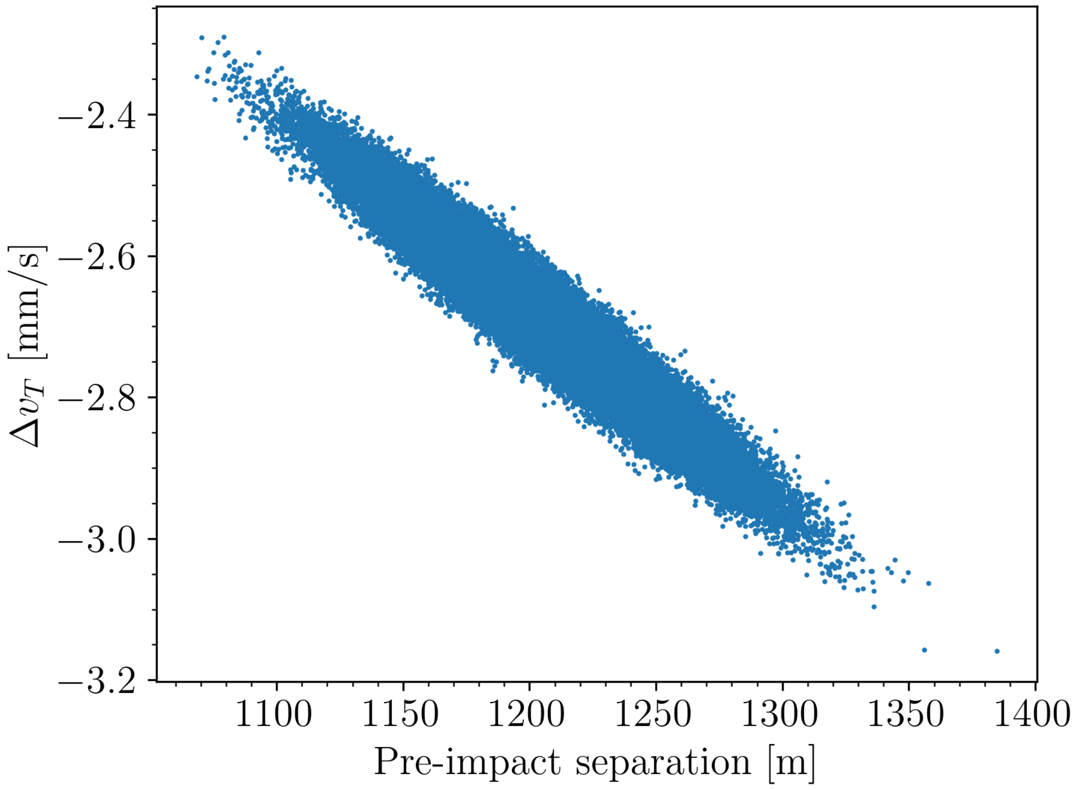


Sub-mm/s measurement of Dimorphos's change in velocity!

Refining Δv_T

Largest source of uncertainty: pre-impact semimajor axis

$$a_{\text{pre}} = 1206 \pm 35(1\sigma)\ \text{m}$$



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$$\frac{P^2}{a^3} = \frac{4\pi^2}{GM}$$

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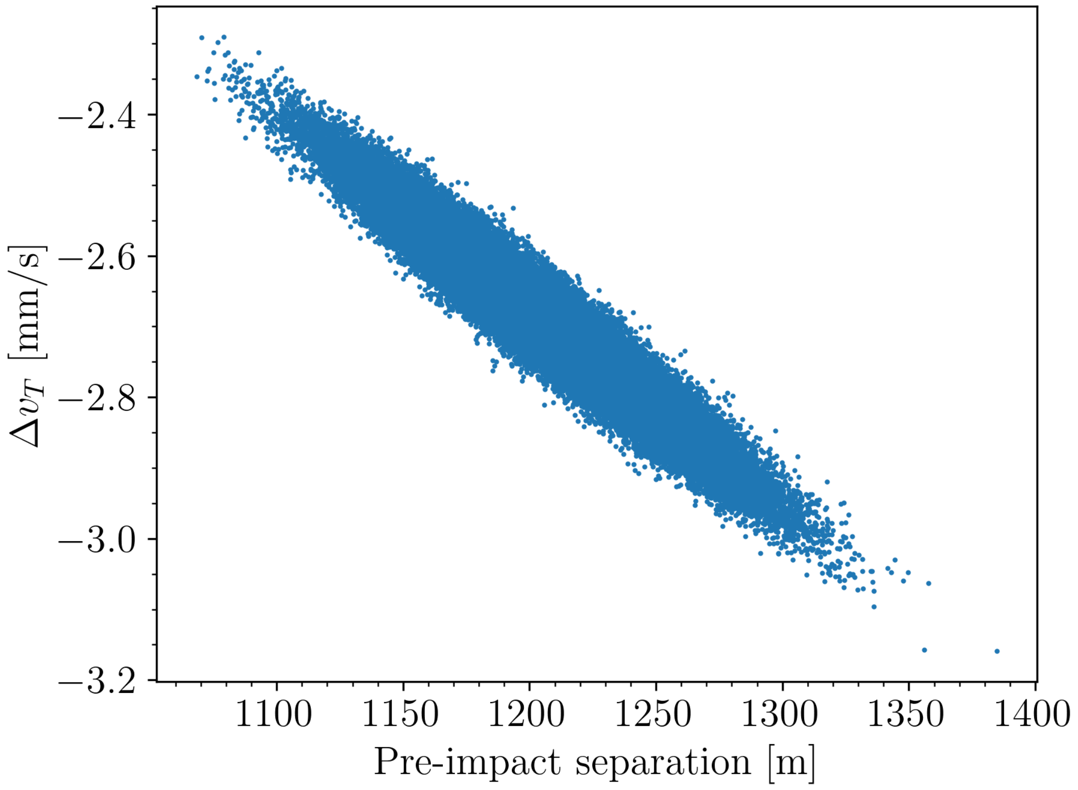

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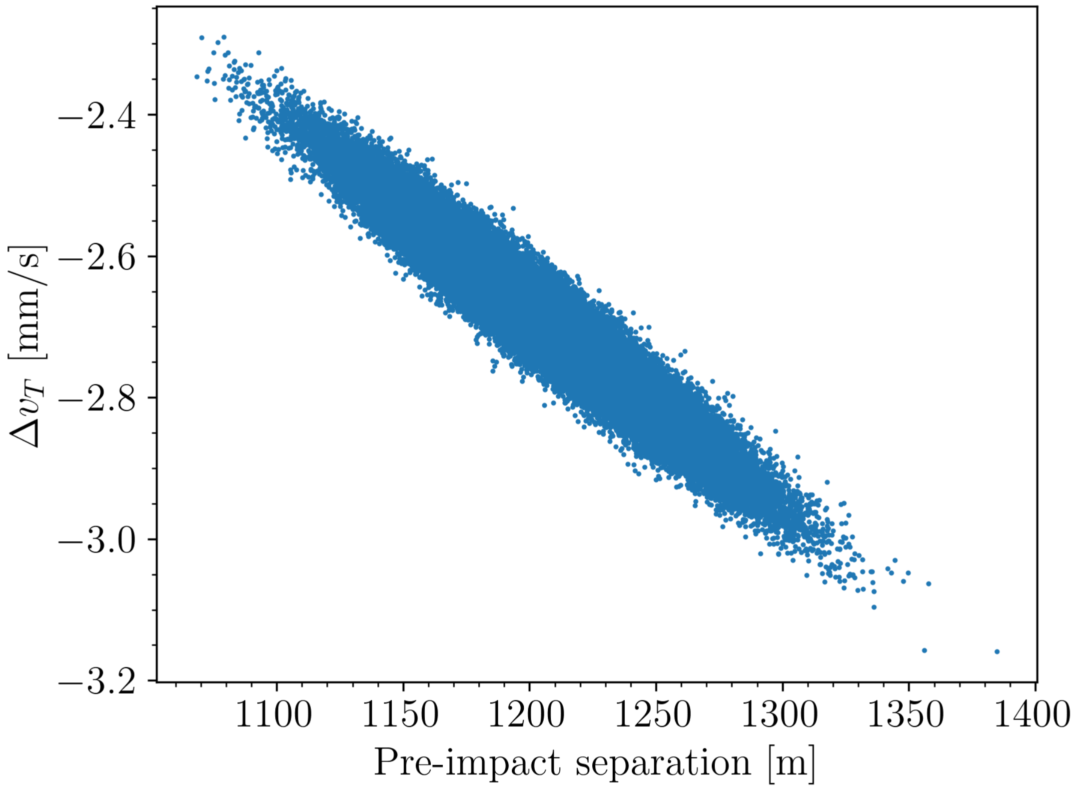

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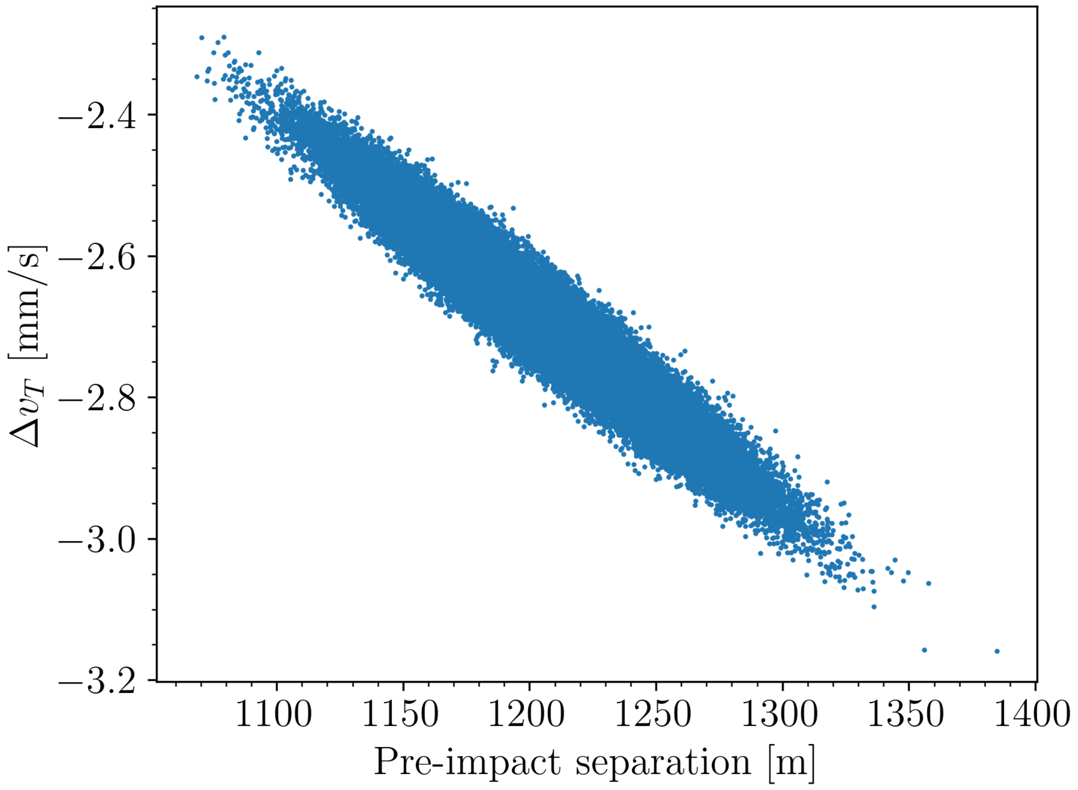

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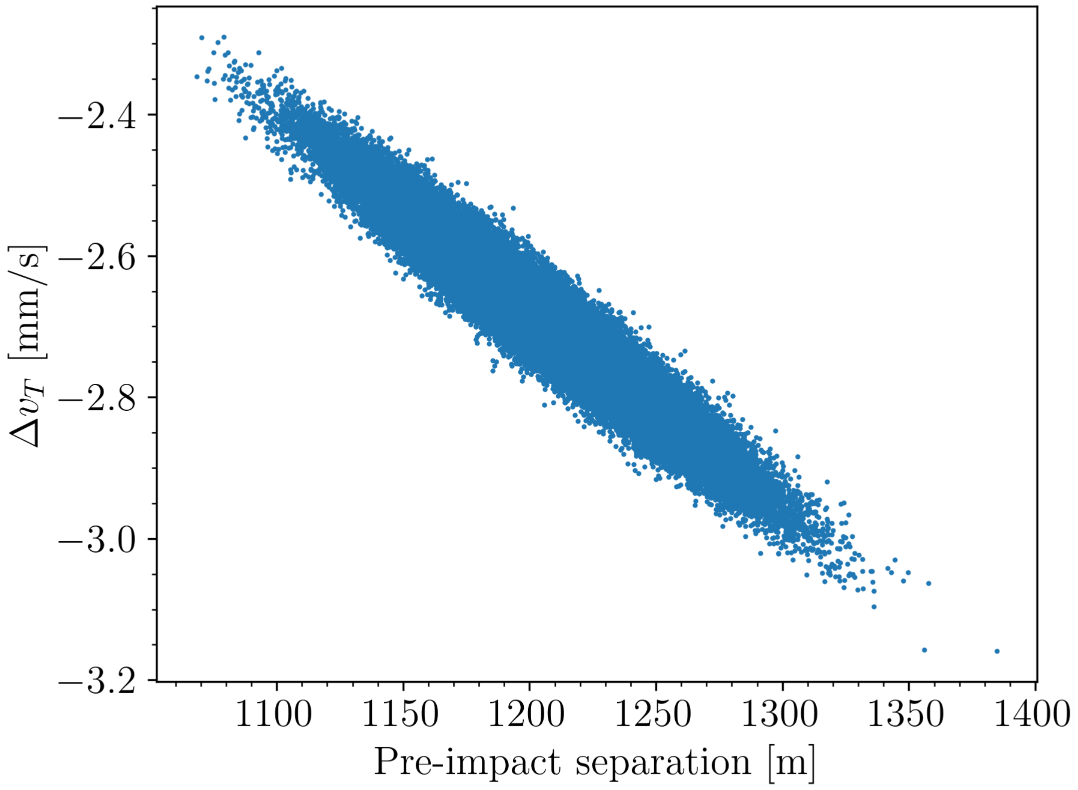

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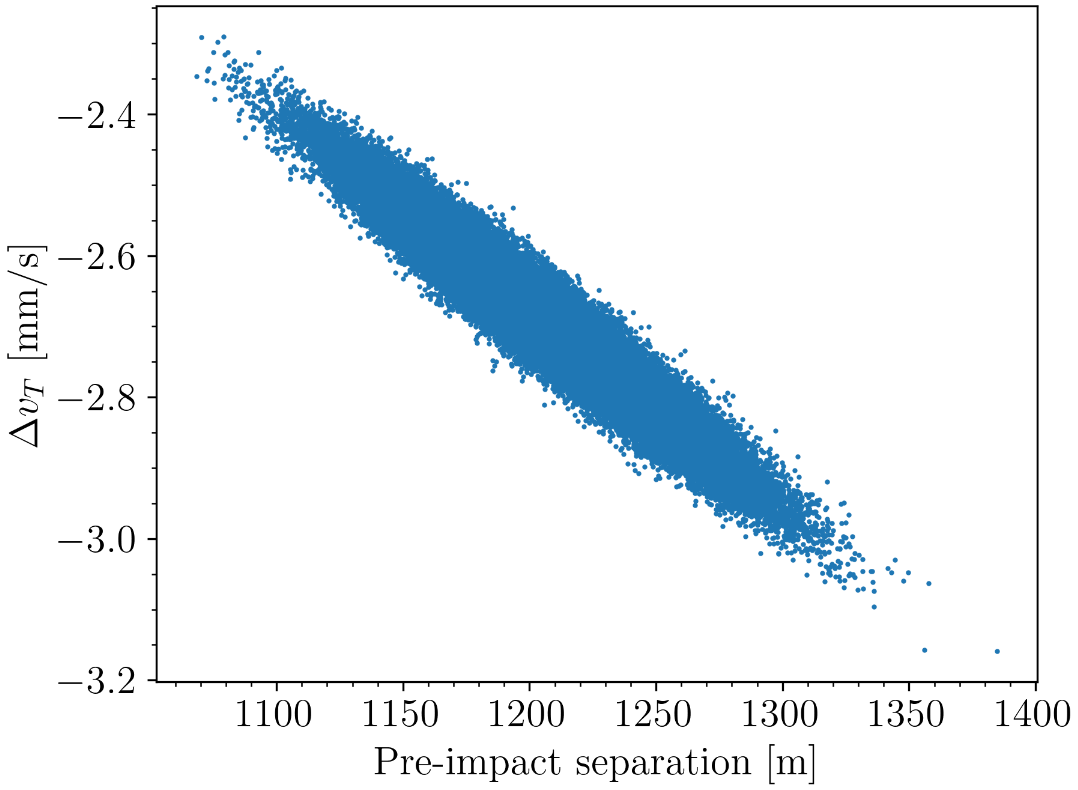

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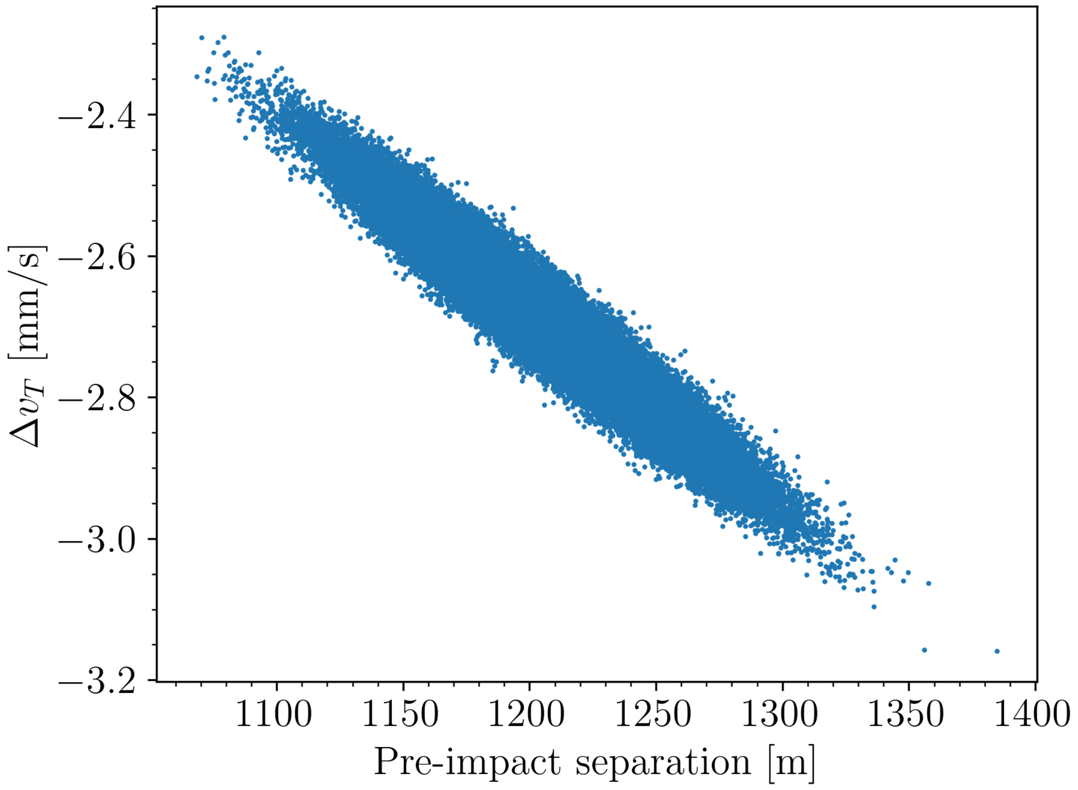

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Well known

Hera!

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Conclusions

- DART significantly altered the binary orbit, reducing the orbital velocity by ~2.7 mm/s and the orbit period by ~33 min
- The measurement of Δv_T (and therefore β) can be substantially improved upon Hera's arrival in late 2026