Possible reaction of Dimorphos to the DART (NASA) collision

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ABSTRACT:
AIDA (Asteroid Impact & Deflection Assessment) is an international collaboration between NASA and ESA which involves both DART (Double Asteroid Redirection Test, NASA) and Hera (ESA) missions. In this work we investigate the possible reaction of Dimorphos (Didymos B) to the DART collision to be performed in 2022, under the assumption that it is a gravitational aggregate produced in the formation of the binary system. The very structure of the target is unknown; therefore, we model it by (1) mono- and multi-dispersed distributions of spherical basic elements and by (2) considering irregular components. We perform numerical simulations of the collision event by using a discrete-element *N*-body numerical code (PKDGRAV).
Here we report on results obtained so far on the effects of the DART impact on Dimorphos structure, including changes in its spin period and direction of the direction of the spin axis. Such predictions may be of interest in the study of the post-impact dynamics of the system –that will be determined by the Hera mission measurements. This, in turn will help in the interpretation of the results of the outcome of the DART impact mission.

Context of the research

- DART Kinetic energy ~9x10^{9} J > Dimorphos self-gravitational binding energy ~2x10^{7}.
- Dimorphos has cohesion forces that compensate for that.

  ➔ But: how can the structure of the overall body be damaged by DART impact?

- Most impact kinetic energy goes into asteroid <u>local</u> material damage (e.g., vaporization, melting, elastic-plastic rock deformation, heat transfer, …).

- Assuming Dimorphos is a gravitational aggregate ('rubble-pile')

  ➔ Surving kinetic energy is delivered to components. (How much?)
- Linear momentum and angular momentum are conserved.

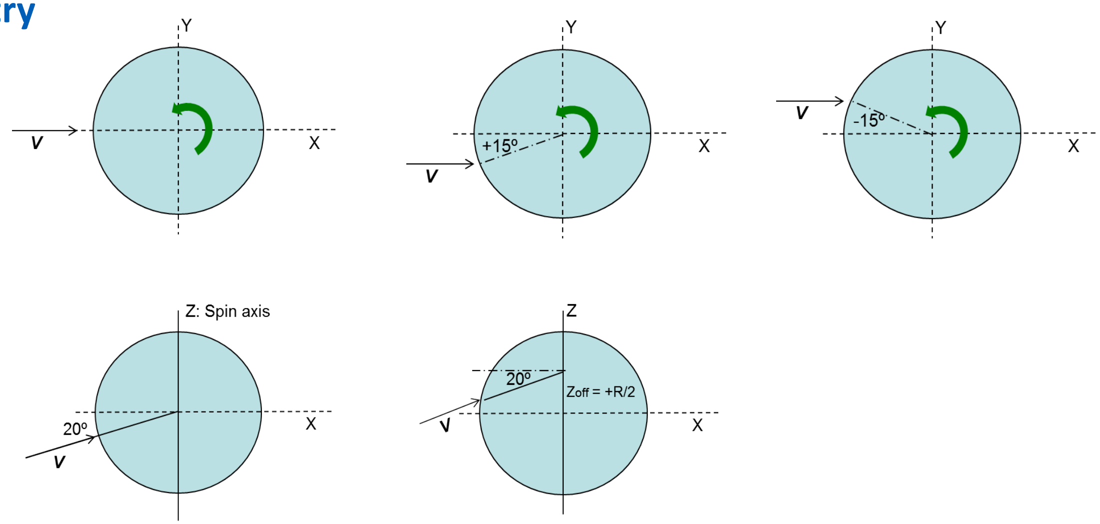
> **Evolution of Didmorphos internal structure depends on propagation of:**
>
> **a) linear/angular momentum, and**
>
> **b) residual kinetic energy (stochastic processes based on multiple low–speed collisions)**

Description of the work

As we do not perform simulations of the shattering phase, we instead concentrate on the effect of the collision on the target, *after* the shattering phase implying material damage (melting, vaporization, heating and deformation), is over. Therefore, our synthetic projectile carries the same nominal momentum as the DART mission does, but it delivers to the target only the kinetic energy expected to survive once the shattering (non-elastic) phase has dissipated most of the impact kinetic energy.

We account for different centre- and off-centre- possible impact geometry compatible with DART nominal impact angle with respect to the target orbital plane.

Impact geometry



Y-offset impact dir.: ± 15º

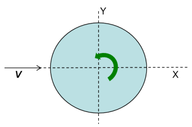
Z-offset impact dir.: ± R/2

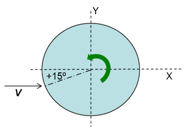
Results: Change in spin period and axis orientation

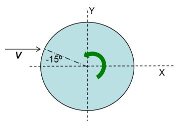
Z0 Z1 Z2

Zenital view

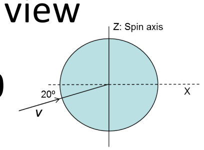
Side view





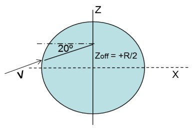


S0



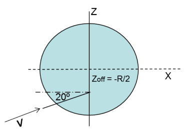
S0Z0 S0Z1 S0Z2

S1



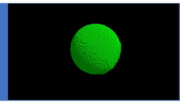
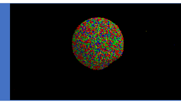
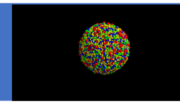
S1Z0

S2



S2Z0

Evolution time: 2.5 Dimorphos spin periods.

	A) Monodisperse 100549 part. d = 3.0 m 		**B) Polidisperse 100000 part. d = 2.0 – 5.0 m** 		**C) Polidisperse 13641 part. d = 3.8 – 9.7 m** 	
	*Δ*T (min)*	*Δ*i (º)*	*Δ*T (min)	*Δ*i (º)	*Δ*T (min)	*Δ*i (º)
S0Z0	-17	0.4	-12	0.0	-22	2.7
S0Z1	-4.3	2.1	-12	2.4	+0.4	2.9
S0Z2	-17	0.4	-14	1.7	-20	0.6
S1Z0	-35	1.1	-11	0.5	-39	0.7
S2Z0	+8.2	0.7	+2.0	0.9	+11	1.2

Impact and prospects for the future

- First results:

  Spin period and **axis orientation** change depending on impact geometry and target structure:
  - Spin period: -39’ to +11’ change.
  - Spin axis: up to 2.9 deg. change.

  - Velocity component normal to Didymos-B orbital plane: 0.23 mm/s.

- To be done next:

  - We need to check shape change and surface velocity field.
  - Explore f_{KE} range.
  - Irregular shape components (non-spherical) and size distribution.
  - Non-spherical target shape.