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Double Asteroid Redirection Test (DART) with LICIACube: Kinetic Impactor Science

Andrew F. Cheng (1), Andy S. Rivkin (1), Nancy Chabot (1), Elisabetta Dotto (2)
(1) JHU/APL Laurel, Maryland USA, (2) INAF-OA, Rome, Italy (andrew.cheng@jhuapl.edu)

Abstract

The NASA Double Asteroid Redirection Test (DART) mission [1] will be the first planetary defense mission and will demonstrate asteroid deflection by kinetic impact. DART will impact the secondary member of the [65803] Didymos binary asteroid system in late September, 2022 in order to modify the trajectory of the moon through momentum transfer. DART is part of the Asteroid Impact & Deflection Assessment (AIDA) international cooperation along with the ESA Hera mission study [2]. DART is the first hypervelocity impact experiment on an asteroid at a realistic scale relevant to planetary defense, where the impact conditions and the projectile properties are fully known. DART will provide validation of the kinetic impactor technique and improve models of kinetic impactor effects to enable applicability to different targets. LICIACube is a 6U cubesat contributed by the Italian Space Agency to the DART mission. DART will carry LICIACube to Didymos and release it to perform a separate flyby of Didymos and to study the DART impact ejecta plume. DART and LICIACube are both approved missions by NASA and ASI, respectively. The Hera mission study is in ESA Phase B1-B2.

1. Introduction

The impact of the 650 kg DART spacecraft at 6.65 km/s on the 160-m Didymos moon will change the binary orbital period by ~10 minutes (more than a 1% change) assuming momentum transfer efficiency β=1. This change will be measured by supporting Earth-based optical and radar observations, since Didymos in September-October, 2022 approaches within 0.075 AU from Earth. Ground-based optical observations of the Didymos light curve will measure the period change via the timing of mutual events, while radar will observe the orbital motions. These measurements determine the orbital velocity change from the DART impact.

2. Momentum Transfer and Hera

A key objective of the DART kinetic impactor demonstration is to determine the momentum transfer to the target asteroid, which is presently uncertain owing to the poorly understood contribution of recoil momentum from impact ejecta. This recoil momentum contribution needs to be extrapolated from the centimeter scale of laboratory experiments by many orders of magnitude with simulations to apply to a kinetic impact for asteroid deflection. DART will measure the orbital velocity change of the target body and will determine the momentum transfer from the known system mass of Didymos and the relative sizes of the Didymos primary and secondary.

The Hera mission, which is the ESA component of AIDA, will rendezvous with Didymos and will directly measure the mass of the Didymos secondary to determine the momentum transfer from the DART impact, without assumptions about the densities of the Didymos components. Hera will also measure the diameter and depth of the DART impact crater. These measurements by Hera can be made several years after the DART impact without any loss of value.

The efficiency of the impact momentum transfer depends on the physical properties and internal structure of the target, notably density, porosity and strength, but also on the local slope of the target surface and on the presence of local structural features like boulders. DART will determine, from terminal approach imaging, the impact location on the target asteroid, the local surface topography and the geologic context. The Hera measurements of the DART crater diameter and depth enable estimation of target physical properties such as strength and porosity.

3. LICIACube Contribution

Structure and evolution of the DART impact ejecta will be studied by the LICIACube spacecraft which is the ASI contribution to DART. LICIACube will be carried by DART close to Didymos and released two or more days prior to the impact, so as to perform a separate flyby of Didymos with closest approach several minutes after the DART impact. It will obtain images of the impact ejecta and their evolution, the DART impact site if the ejecta plume is sufficiently transparent, and the non-impact hemisphere of the target asteroid.

The LICIACube observations of the DART ejecta plume make an important contribution to the determination of momentum transfer from the DART impact, by providing information on the ejecta plume momentum and particularly its direction relative to the DART approach vector.

4. Summary and Conclusions

DART with LICIACube and Hera together fulfill the vision of AIDA to perform the first fully documented hypervelocity impact experiment on an asteroid at a realistic scale for planetary defense. This experiment will validate the kinetic impactor technique and reduce risks for future asteroid hazard mitigation.

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References

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