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OpGrav - Implications for Planetary Defense

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This research describes a method for resolving the mass of asteroids and comets during flybys. In this concept, called Optical Gravimetry or *OpGrav*, a host spacecraft releases a group of small white spheres, which it then tracks using an on-board telescope. The spheres, which act as passive test-masses and are called probes, are deployed such that they pass very near to the small body and their trajectories are measurably perturbed (Figure 1). A spacecraft-mounted camera determines the relative measurements of the probes, including right ascension and declination angles. These measurements are then processed on the ground and used to estimate the small body's mass.

The relative measurements have the advantage of being high signal-to-noise and high resolution, owing to the short distance between the host spacecraft to the probes and the probes to the small body. They are also numerous, since multiple probes can be deployed from a single spacecraft, possibly to different relative geometries. These benefits enable the accurate determination of mass for bodies that are too small to study using typical ground-based radiometric tracking with distant flybys.

Miller, Barbee, and Morrison[1] find that asteroid mass and porosity are critical parameters for planetary defense research. Mass relates directly to the potential impact consequences as well as the available mitigation options. Coupled with a shape model, a mass estimate constrains the small body's bulk porosity. Porosity relates to the asteroid's response to an impact, including the predicted momentum-enhancement factor, β. This characterization has implications for available mitigation options as well.

The most accurate method of determining mass and bulk porosity is via spacecraft tracking[2], either from rendezvous or flyby. The measurement is easily achievable from a dedicated rendezvous orbit, but

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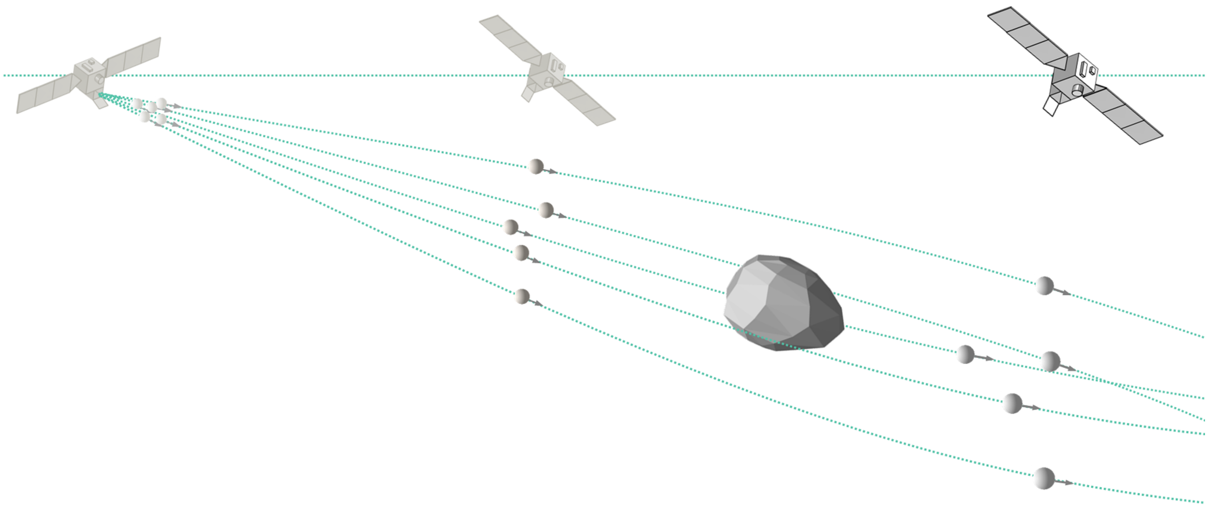

Figure 1: **OpGrav Concept-of-Operations. A host spacecraft deploys probes prior to an asteroid flyby, and then optically tracks them before and after close-approach.**

doing so typically requires a significant amount of propellant. To date, only 5 bodies have had their mass estimated from flyby data, despite approximately 19 spacecraft flybys of an asteroid or comet. Flybys require much less spacecraft propellant and are often added opportunistically to missions with non-asteroid targets. OpGrav seeks to improve the feasibility and accuracy of small body mass determination from spacecraft flybys. One challenge for typical techniques is that spacecraft missions need to balance competing objectives. Gravity science requires low flyby altitudes that yield a measurable perturbation on the spacecraft's trajectory. However, low altitudes can preclude imaging science, since doing so requires increasingly fast slew rates near close-approach. Even more, low altitude flybys require very precise navigation to ensure mission safety and accurate instrument pointing. OpGrav decouples these objectives by enabling the spacecraft to pass at a safe distance optimized for imaging science, while the probes experience the measurable perturbations associated with a low flyby.

This paper estimates the near Earth asteroid population whose mass could be determined from flybys using OpGrav. This is achieved by parametrically evaluating OpGrav sensitivity over relevant asteroid sizes and flyby speeds.

Comments:
Preference for oral presentation.

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