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Ongoing and Upcoming Mission Highlights

HYPOTHETICAL ASTEROID 2023 PDC MASS MEASUREMENT VIA DOPPLER GRAVIMETRY IN A RECONAISSANCE FLYBY

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ABSTRACT

Mass, density, and porosity of a potentially hazardous asteroid (PHA) are critical characteristics to measure and understand in order to estimate the possible damage to Earth from an impact and to design mitigation strategies [Barbee, 2020]. Rapid reconnaissance flyby missions are an important option for quickly characterizing a PHA. In a traditional flyby, the asteroid mass is obtained by using Earth-based ranging and Doppler measurements to track the spacecraft as its orbit is perturbed by the asteroid's gravity. However, this technique is limited to asteroids larger than approximately 3-5 km in diameter, even with very favorable flyby conditions. This means that flybys cannot supply precise mass, density, or porosity measurements for many of the most concerning asteroids.

This study evaluates the feasibility of using a new technique known as Doppler Gravimetry (DopGrav) to return a mass measurement from a high-speed spacecraft flyby of the hypothetical asteroid threat, 2023 PDC. At the time of discovery, 2023 PDC has an estimated diameter of 500 m making it too small for the asteroid's mass to be observable using Earth-based tracking of the flyby spacecraft. DopGrav augments the Earth-based tracking with additional Doppler and optical measurements from the spacecraft to one or more CubeSat test-masses that pass much closer to the asteroid, significantly improving the sensitivity of the mass measurement. The CubeSat test-masses are nominally 6U in size and use a concept of operations similar to what was recently used by LiciaCUBE and DART [Dotto, 2021]. They are deployed by the host spacecraft approximately two weeks prior to close approach with 2023 PDC. They have their own propulsion systems allowing them to perform their own targeting maneuvers to achieve the desired close approach distances.

Prior work by the authors has shown that a related technique using relative optical measurements of passive test-masses can measure the mass of asteroids as small as 400-500 m in diameter (see, e.g. [Bull et al., 2021]), which leaves little margin if 2023 PDC turns out to be smaller than believed at discovery. Christensen et al. showed that DopGrav with GRAIL-like measurement precision can measure the mass of asteroids as small as 100 m in diameter, which requires two highly sophisticated spacecraft [Christensen et al., 2021]. The use of a CubeSat-based test-mass for this study gives increased precision over passive test-masses, while using proven deep space CubeSat technology to develop a relatively simple add-on to a flyby reconnaissance mission.

We will show the expected mass measurement performance of this CubeSat-based DopGrav architecture for a notional reconnaissance flyby mission to 2023 PDC. In the event that 2023 PDC turns out to be significantly smaller than expected, DopGrav may still provide a meaningful upper bound on the mass, bounding the potential damage and mitigation options.

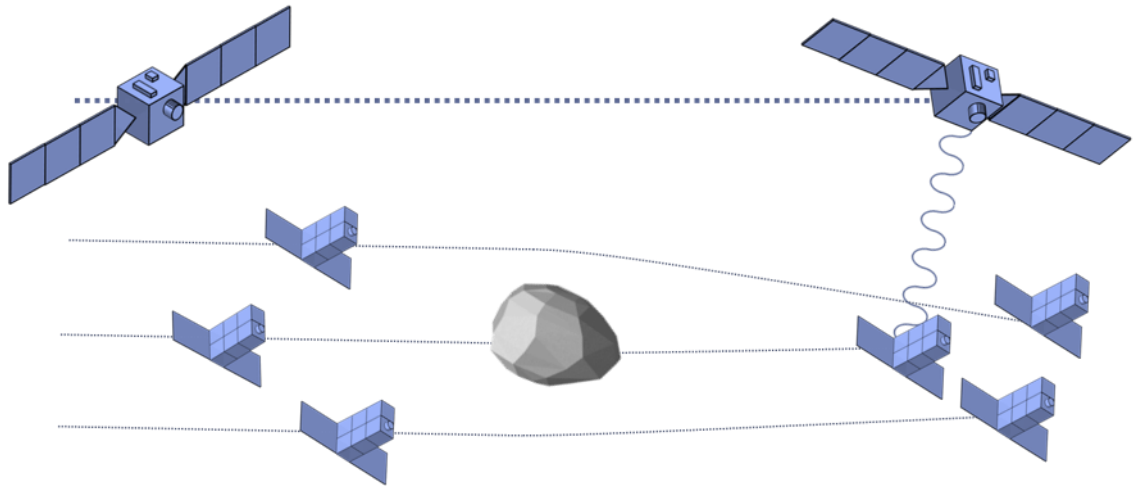

Figure 1: Overview of the DopGrav concept. The CubeSats are deployed weeks before the encounter with 2023 PDC and are tracked optically and radiometrically by the host spacecraft, significantly improving the sensitivity of a mass measurement.

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Comments:

We selected the session, "Current and Upcoming Missions" because the focus of our study is the 2023 PDC hypothetical encounter. Please select a different session if this is not appropriate.