CONSTRAINING THE DENSITY DISTRIBUTIONS OF ASTEROIDS VIA CLOSE ENCOUNTERS. Jack T. Dinsmore[1] and Julien de Wit[2], [1]Stanford University, Stanford, CA 94305, jtd@stanford.edu, [2]Massachusetts Institute of Technology, Cambridge, MA 02139.

Introduction: Knowledge of the interior density distribution of an asteroid can reveal its composition and constrain its evolutionary history. However, most asteroid observational techniques are not sensitive to interior properties. We investigate the interior constraints accessible through monitoring variations in angular velocity during a close encounter.

Methods: We derive the equations of motion for a rigid asteroid's orientation and angular velocity to arbitrary order and use them to generate synthetic angular velocity data for a representative asteroid on a close Earth encounter. We develop a toolkit AIME (Asteroid Interior Mapping from Encounters) which reconstructs the asteroid density distribution from these data, and we perform injection-retrieval tests on these synthetic data to assess AIME's accuracy and precision. We also perform a sensitivity analysis to asteroid parameters (e.g. asteroid shape and orbital elements), observational set-up (e.g. measurement precision and cadence), and the mapping models used (figure 1).

Results: Observations of tumbling asteroids before or after the encounter allows the extraction of moment of inertia ratios. To extract further density information, we find that high precision in rotational period measurements and low perigees are required.

Under some models, the density of large-scale non-uniformities can be found to ~0.1% uncertainty as long as the uncertainty of rotational period measurements is <0.27 seconds and the perigee is <18 Earth radii, for an asteroid similar to 99942 Apophis.

We expect Apophis's 2029 encounter to provide enough data to place constraints on its interior density distribution, given a precise enough observational campaign.

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References:

[1] Jack T. Dinsmore and Julien de Wit (2023) *MNRAS, 520 (3), 3459–3475.*

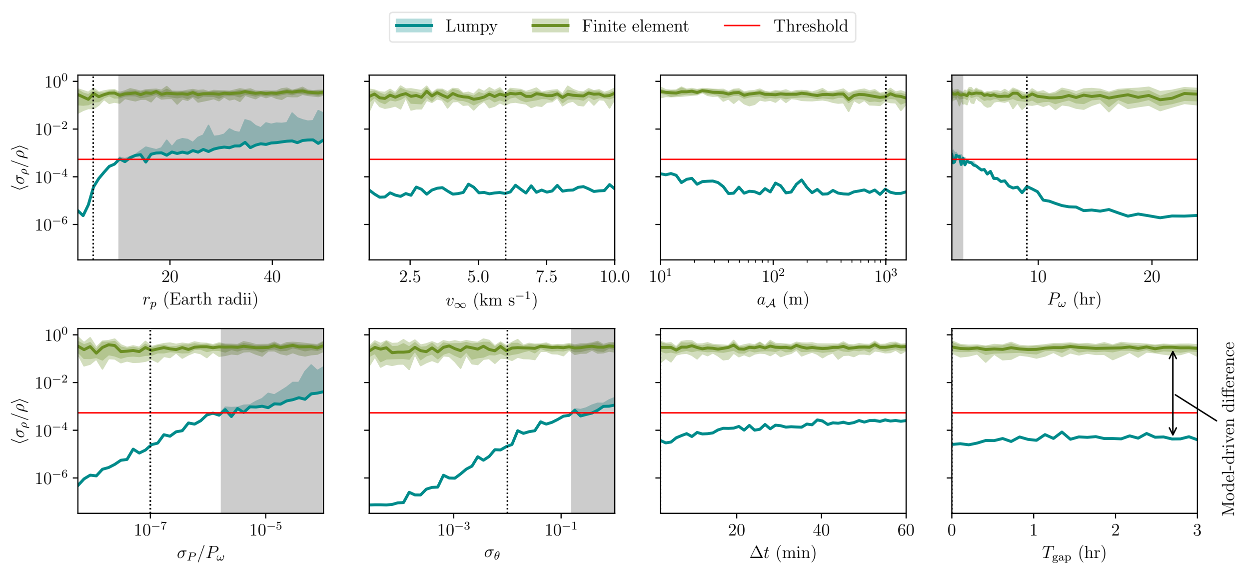

Figure 1: Average ratio of density uncertainty to density across an asteroid as extracted by AIME for an Apophis-like simulated flyby. The two lines show two asteroid density models. Density uncertainty is shown as a function of perigee, hyperbolic excess velocity, radius, and rotational period (top row), and rotational period uncertainty, spin pole direction uncertainty, cadence, and potential gaps in data (bottom row). The unshaded regions give satisfactory constraints on density. The physical parameters of Apophis's 2029 encounter are favorable enough to constrain its density distribution given a precise enough observational campaign.