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CONSTRAINTS ON DENSITIES OF SMALL NEOS FROM RADIATION PRESSURE DETECTIONS

Marco Micheli[1], David J. Tholen[1], and Garrett T. Elliott[1]
[1]*Institute for Astronomy, University of Hawaii,*
2680 Woodlawn Dr, Honolulu, HI 96815, USA,
+1-808-956-5448, micheli@ifa.hawaii.edu

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ABSTRACT

In the last few years the increased number of telescopes dedicated to NEO survey, and their greater depth and sensitivity to fast-moving objects, has allowed the discovery of a large number of very small NEOs, in the 1 to 10 meter range. Most of these objects are only observed in a short time window of a few days, around their time of fly-by with our planet. However, on occasion, the geometry of the encounter is particularly favorable, and the object remains observable for a longer time span, sometimes up to many months.

Starting in 2010 we tried to obtain extended astrometric coverage for the most promising objects in this class, using many different telescopes on Mauna Kea, in Hawaii. The ability to detect targets down to a magnitude of about V=25, combined with the use of high-precision astrometric techniques, allows us to analyze the dynamics of these objects in great detail.

These very small asteroids are interesting test cases for the detection of non-gravitational accelerations, because of their small mass. The drift from a purely gravitational orbit can be easily detected with just optical astrometry only, if the observed arc is long enough and densely covered with observations.

In the size regime we are interested, between 1 and 10 meters of diameter, the dominating non-gravitational effect is the pressure caused by solar radiation hitting the object, and being either reflected or absorbed from its surface (in a fraction dependent on the object's albedo). Since the force on the object is proportional to its cross-section facing the Sun, the resulting acceleration will scale with the ratio between the object's cross-sectional area and its mass, and can be parameterized with a single number, the Area to Mass Ratio (AMR, or A/M). This additional parameter (and its error bar) can be estimated in an orbital determination process, by fitting it together with the usual 6 orbital elements.

When the AMR of an object can be determined, it is possible to use it to extract interesting physical information on the asteroid. In particular, if it is possible to obtain independent constraints on the size of the object, the mass could be decoupled from the AMR and used to estimate its bulk density.
This is trivial if the absolute magnitude and the albedo of the object are known. However, the latter is unknown in most cases, since these small objects are usually too faint for a direct thermal detection, or even for a rough spectral classification. In these cases, it is still possible to use a distribution of typical asteroidal albedoes to obtain interesting constraints on the density, by convolving the probability distribution of the albedo with all the other measurable quantities.
In this work we will present the most recent results of this analysis. At the time of this writing our sample contain four objects that have been observed well enough to extract a meaningful radiation pressure detection. For all of them the computed range of possible bulk densities is extremely low, with nominal values ranging from about 450 kg/m^3 to 700 kg/m^3, and 1-sigma uncertainties typically around 300 kg/m^3 (and almost entirely due to the width of the assumed albedo distribution). For all four objects the probability distribution for the density is such that the likelihood of a value higher than water is 20% or less, and typical rock densities are excluded to a confidence level greater than 98%.
We will also discuss the implications of this result for the estimate of impact hazard from very small objects. These density values seem to require an extremely high porosity, but the existence of some fast rotators in the sample also implies the existence of some kind of tensile strength in the material, pointing to a monolithic structure and excluding a rubble-pile composition.
It is possible that similarly low densities may also be common in targets of larger size, and greater relevance in terms of impact monitoring. If that is the case, the consequences of an impact with a small-sized asteroid (up to Tunguska scales) may need to be revised to take into account a lower mass, and different fragmentation and disintegration processes in the atmosphere.
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