Thermal inertia and bulk density of near-Earth asteroids

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Thermal inertia and bulk density are two important properties that describe the surface morphology and internal structure of asteroids. Since thermal inertia depends predominantly on regolith particle size and depth, degree of compaction, and exposure of solid rocks and boulders within the top few centimeters of the sub-surface, it can be used to infer the presence or absence of loose material on the asteroid surface [1,2]. When the asteroid bulk density is compared with that of meteorites associated with the asteroid spectral type, then it allows the macro-porosity of the asteroid to be determined. The macro-porosity can then be used to infer whether the asteroid is predominantly a solid body throughout, a fractured body, or a rubble-pile [3]. Each structural classification gives different insights into how the asteroid formed and evolved.

The thermal inertia and bulk density can be determined by simultaneous thermophysical modeling of thermal-infrared and Yarkovsky orbital drift observations. Thermal inertia is a measure of a material's resistance to temperature change and dictates the asteroid surface temperature distribution. Different thermal inertia values can be detected in thermal-infrared observations, and can be inferred by using a suitable thermophysical model that takes into account the asteroid's shape, rotation state, surface roughness, and observing geometry. The surface temperature distribution influenced by thermal inertia causes a morning-afternoon temperature asymmetry, which leads to an excess of thermally emitted photons on the afternoon side. This excess of photons applies a very small force to the afternoon side of the asteroid, which causes the orbital semimajor axis to increase or decrease slowly over time, depending on whether the asteroid is a prograde or retrograde rotator (i.e., the Yarkovsky effect [4]). The rate of Yarkovsky semimajor axis drift is dictated by the asteroid thermal inertia and bulk density, amongst other important properties, and can be modeled by using a similar thermophysical model to that which is used to interpret thermal-infrared observations. Model-to-measurement comparisons of the Yarkovsky semimajor axis drift can then allow the asteroid bulk density to be determined.

The Advanced Thermophysical Model (or ATPM) is the only thermophysical model currently available that can simultaneously interpret thermal-infrared observations and make Yarkovsky effect predictions [2][5][6]. It has already been used to determine the thermal inertia and bulk density of near-Earth asteroids (1620) Geographos [7], (1862) Apollo [8], and (101955) Bennu [9], and has also been used to investigate the asteroid YORP effect (i.e., asteroid spin-state changes caused by the asymmetric reflection and re-radiation of sunlight from an irregular shape [4]). In the current work presented here, the ATPM has been applied to near-Earth asteroids that have suitable thermal-infrared, shape model, and Yarkovsky effect datasets in the available literature in order to significantly increase the number of characterized near-Earth asteroids. This involves exploiting the DAMIT [10] and radar [11] shape model databases, the lists of current Yarkovsky detections [12][13], and the NEOWISE catalogue of observed near-Earth asteroids [14] as well as other available sources. By combining our investigation with previously published studies of individual near-Earth asteroids, we aim to more deeply investigate the apparent trend of increasing thermal inertia with decreasing diameter [1], and seek any relationships that exist between thermal inertia, bulk density, and other asteroid properties. The latest results will be presented and discussed.

References: [1] Delbo et al., 2007, Icarus, 190, 236. [2] Rozitis & Green, 2011, MNRAS, 415, 2042. [3] Britt et al., 2002, Asteroids III, 485–500. [4] Bottke et al., 2006, AREPS, 34, 157. [5] Rozitis & Green, 2012, MNRAS, 423, 367. [6] Rozitis & Green, 2013, MNRAS, 433, 603. [7] Rozitis & Green, 2014, A&A, submitted. [8] Rozitis et al., 2013, A&A, 555, A20. [9] Chesley et al., 2014, Icarus, in press. [10] Durech et al., 2010, A&A, 513, A46. [11] http://echo.jpl.nasa.gov/asteroids/shapes/shapes.html. [12] Nugent et al., 2012, AJ, 144, 60. [13] Farnocchia et al., 2013, Icarus, 224, 1. [14] Mainzer et al., 2011, AJ, 743, 156.