Using binary asteroids to explore the interior geophysics of rubble-pile asteroids

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The internal geophysics of small rubble-pile asteroids are largely unexplored, with standard geophysical theories of strength and dissipation not being well matched to the extreme environment these bodies exist in. Interior pressures within rapidly spinning rubble piles are computed to be as small as a few Pascals, a regime in which small non-gravitational forces not considered for larger bodies may become important. The limited research done on the geophysics of such bodies has suggested that the standard geophysical models for internal energy dissipation in this regime require significant modification [1], changing some of the fundamental relations between size and strength.

Binary asteroid systems provide a unique opportunity for developing constraints and deeper understanding of the magnitude and operation of tidal dissipation within rubble-pile bodies. Recently, Jacobson and Scheeres [2] proposed that the most common class of binary asteroid systems, those with a synchronized secondary and rapidly spinning primary, may be in an equilibrium state where contractive Binary YORP forces balance against expansive tidal torques due to tidal distortion of the primary body. In such systems it becomes possible to develop estimates of the ratio of tidal dissipation number over tidal Love number, Q/k. The predicted equilibrium semi-major axes for such binary asteroid systems (based on presumed values for the Binary YORP force and Q/k values) has been seen to be consistent with the observed sizes of many of these systems (see figure). To refine the estimates for this ratio it is necessary to both confirm the existence of binary asteroids in such an equilibrium state and develop a better understanding of what value the Binary YORP coefficient of binary systems will have [3].

Recently, it has been verified that the spacecraft-accessible binary asteroid 1996 FG_3 is in such an equilibrium state [4]. The combined detection of such an equilibrium coupled with knowledge about this binary system makes it feasible to sharply constrain the Q/k parameter for the primary asteroid in the 1996 FG_3 system and extrapolate its functional form to other such systems. We will review the theory and measurements that make such a determination feasible, and explore other geophysical aspects of such a system that could be determined from a rendezvous space mission.

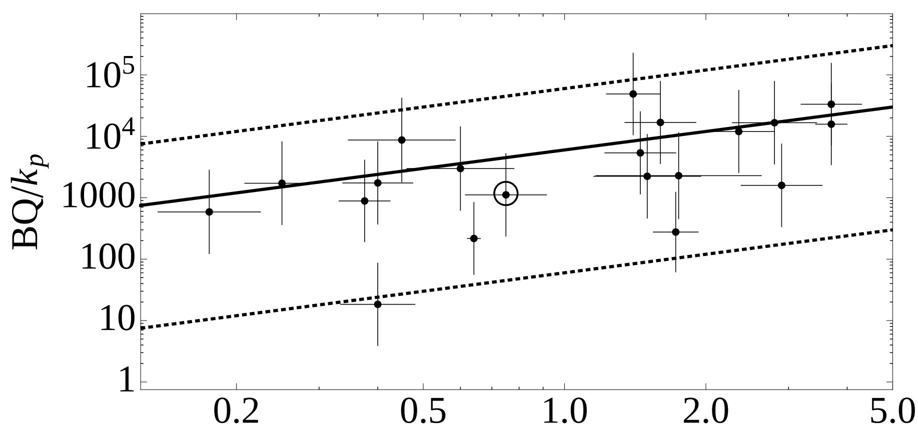

Figure: Singly-synchronous binary system primary radii are plotted against their determined value of BQ/k, based on their current semi-major axis [2]. The circled point is for asteroid 1996 FG_3. Values of the BYORP coefficient B are on the order of 0.001 with an order of magnitude uncertainty, providing initial estimates on Q/k. Proposed approaches for measuring B, and hence Q/k, will be discussed.

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References: [1] Goldreich and Sari, ApJ 691:54, 2009. [2] Jacobson and Scheeres, ApJL 736:L19, 2011. [3] McMahon and Scheeres, Icarus 209: 494–509, 2010. [4] Scheirich et al., Binaries Workshop 2013.