Binary near-Earth asteroids: Satellite spin states under spin-orbit coupling

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We numerically investigated the effects of spin-orbit coupling on the spin states of satellites in binary near-Earth-asteroid (NEA) systems. About 15 % of all NEAs larger than 200 meters are estimated to be binaries [Margot et al. 2002, Pravec et al. 2006]. To date, about 50 binary NEAs (including at least two triple NEAs) are known but less than a dozen have well-determined mutual orbital parameters (semimajor axes and eccentricities), component mass ratios, and spin rates (synchronous or asynchronous). The well-characterized binaries and triples have semimajor axes that range between ∼3 and ∼20 times the radius of the primary, eccentricities that range between ∼0 and ∼0.7, and secondary-to-primary mass ratios that range between ∼0.05 % and ∼6 % [Fang & Margot 2012]. The spin angular momenta of secondaries in many of these systems amount to a non-negligible fraction of the system's angular momentum budget [e.g., Margot et al. 2002, Ostro et al. 2006], and it has been suggested that the mutual orbits and secondary spins are highly coupled, affecting the onset of Hyperion-like chaos [Wisdom et al. 1984].

For our simulations, we integrated the equations of motions for the translational and rotational motions of the components in the primary body-fixed reference frame, as derived by Maciejewski 1995. We computed forces and torques on the components by taking derivatives of the mutual potential between the two bodies expressed in terms of their inertia integrals expanded to fourth degree [Ashenberg 2007]. The integrator is capable of handling arbitrary shapes, mass distributions, and non-planar configurations, which is more general than the formalism of McMahon & Scheeres [2013]. We explored the phase space with our coupled spin-orbit integrator, and we identified regions of regular and chaotic motion on Poincaré maps. Even regular cases result in large libration amplitudes and large spin-rate variations. These have implications for the strength of binary YORP, which is hypothesized to modify orbits of synchronous satellites on rapid timescales [McMahon & Scheeres 2010, Ćuk & Nesvorný 2010]. These spin-rate variations are also important for interpreting radar data, as the Doppler widths are spin-rate-dependent.

We will discuss the dynamical regimes of existing, well-characterized binaries, some of which exhibit evidence for asynchronous satellites or large spin-rate variations.

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