The Life-Cycles of Small Asteroid Systems. D.J. Scheeres[1] and S.A. Jacobson[2], [1]University of Colorado (429 UCB, Boulder, CO 80309-0429, scheeres@colorado.edu), [2]Nice Observatory (seth.jacobson@oca.eu).

Introduction: The recent verification that small asteroids are rubble piles subject to the YORP effect has wide-ranging consequences for the life cycles of these bodies. As the spin rate of an asteroid changes, its minimum energy configuration can change and lead to profound shifts in how its mass is distributed. If the spin rate continues to increase it becomes possible for an asteroid to fission into multiple pieces, forming a binary asteroid. These proto-binary asteroids can follow several fundamentally different paths as a function of their initial morphology, including mutual escape, re-impact, and transition into a stable binary system. Recent in situ and remote observations of asteroids support this picture, and imply that the smallest members of the asteroid family lead an active and interesting life.

Details: This talk will summarize our recent research on the formation, evolution and destruction of multiple component small body systems for asteroids less than ~10 km in size. There are several relevant elements of our theory that we will present, with most of these making comparisons to actual observations and compiled information about binary systems – both current and past. These elements are briefly listed in the following:

Dynamics of Fissioned Bodies: Once a rubble pile asteroid goes through a fission process there are very clear and unambiguous dynamical processes which occur. These have been explicitly described in [1] and include results on the stability of fissioned bodies, when fissioned bodies can subsequently spontaneously disrupt, and when they are expected to remain trapped in a binary system. Elements of this theory have been explicitly "proven" through observations of asteroid pairs [2].

Evolution of Fissioned Bodies: Once a body has undergone a fission process there are several different pathways that the system can take. In [3] we outline these pathways and find clear differences depending on the mass ratio of the system. If the mass ratio between the fissioned components is less than ~0.2 the system will either escape or, prior to escape, be spun so fast as to undergo another fission event. These "secondary fissions" can actually stabilize the system and result in a stable and bound binary that is then subject to long-term evolutionary behavior. If the mass ratio is greater than ~0.2, then the system will preferentially settle into a stable, doubly synchronous state and evolve along a markedly different evolutionary path.

End States of Fissioned Systems: We find several different end states of these fissioned systems [3], all of which have been observed in the small body population. Most significantly, we find that stabilized low mass ratio systems (where the secondary is synchronous) can evolve into a stable binary equilibrium state if the BYORP effect is contractive and if the primary is spins at a super-synchronous state [4]. In this state the BYORP effect is balanced by tidal dissipation in the primary, and is consistent with the majority of observed small binary asteroids. The existence of these equilibria is exciting as they provide the possibility of constraining the internal geophysical parameters of the primary.

In addition to the above published discussions, we will present several additional insights into the long-term evolution of binary systems. These are from papers in preparation and touch on several additional classes of small body systems.

References:

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[3] S.A. Jacobson and D.J. Scheeres. 2011. "Dynamics of Rotationally Fissioned Asteroids: Source of Observed Small Asteroid Systems," Icarus 214(1): 161-178.

[4] S.A. Jacobson and D.J. Scheeres. 2011. "Long-term Stable Equilibria for Synchronous Binary Asteroids," The Astrophysical Journal Letters, 736:L19 (5pp).