CREATION AND DISSOCIATION OF BINARY ASTEROIDS. D.J. Scheeres, *U. Colorado, Boulder (scheeres@colorado.edu)*.

The YORP effect has been identified as a possible formation mechanism for binary asteroids. It works by increasing the spin rate of an asteroid till it reaches a "fission limit" and splits into a binary asteroid. How this fission process operates on realistic asteroid models is a fundamental question we try to address and is a direct function of how the asteroid is modeled. If an asteroid is modeled as a collection of gravitationally bound gravel, its fission process would resemble that of a fluidic body, albeit with friction. However, high resolution imagery of asteroids has shown that their constituents have significant distributions of size scales ranging from subcentimeter gravels through boulders with sizes ranging up to tens of meters and larger. The asteroid Itokawa is a case in point, and appears to be two rubble piles resting on each other, suggesting a model where collections of boulders are resting on collections of boulders. The response of bodies such as Itokawa to a steadily increasing rotation rate will undergo a different evolutionary process as compared to a uniform distribution of material of the similar size.

There are three phases of evolution for such a collection as its spin rate increases: what transitions occur for a rubble pile as its spin rate increases, what happens when the asteroid approaches and passes the fission spin rate, what happens once the body has fissioned into two or more pieces orbiting each other. The important questions and responses of this system are strikingly different for each of these phases, and involve different issues of mechanics and dynamics at each stage. Basic results for how such systems respond to this environment using simple models of asteroid shapes has been investigated in the past (Scheeres, *Icarus* 189: 370-385, 2007). More recently, a methodology for interpreting the evolution of a more realistic model has been derived in (Scheeres, *Planetary & Space Science*, in press). This abstract summarizes the main features of these studies and makes a number of observations relevant to the creation and evolution of binaries and contact binary asteroids.

Minimum energy configurations As the asteroid rotation rate increases (or decreases) the important questions involve the total energy of the collection of bodies for different configurations at a fixed angular momentum. If we model the system as a collection of rigid bodies resting on each other we can express the total energy and angular momentum of the system as the sum of the rotational kinetic energy of each object, relative to the system center of mass, and the sum of the potential energies between every body. As the rotation rate (and angular momentum) of the body increases the minimum energy configuration of the collection can change, placing the system into an unstable configuration. Once such a transition occurs, the system is "perched" and is susceptible to undergoing a landslide given a small disturbance. The aftermath of such an asteroid landslide may be minimal, some gravel rolling downhill, or may be major and involve large numbers of boulders rolling across each other. For simple systems, such as an ellipsoid and sphere resting on each other, these transitions can be exactly computed. For more complex systems, such as a collection of rigid bodies resting on each other, algorithms for computing transitions between energy states can be explicitly derived.

Fission Conditions and free energy As the body spin rate continues to increase two portions of the body will eventually achieve orbital rates relative to each other. When dealing with collections of rigid bodies, these orbital rotation rates occur much earlier than the usual "surface disruption rate". A specific example would be the fission rate of two spheres of equal density resting on each other. If one of the spheres has a small radius, the system will fission at the surface disruption rate. If, instead, the two spheres have an equal radius fission will occur at half the rate. For collections of rigid bodies resting on each other a similar decrease in fission rate occurs, the minimum fission rate of the system being dictated by the two collections whose centers of mass are most distant from each other. For Itokawa, the separation between the "head" and "body" of that asteroid controls this minimum fission rate, and occurs for rotation periods on the order of 6 hours (Scheeres et al., *Icarus* 188: 425-429, 2007).

Stability of proto-binary asteroids Once fission of the system occurs the evolution and ultimate fate of this "proto-binary" depends on the mass distributions of each component. The most important quantity is the free energy, defined as the total energy of the system minus the self-potential energy of each component. If the free energy of the system is positive then the orbital configuration that the system fissions into is unstable and the two components can escape from each other. In this situation the proto-binary is almost immediately dissociated and creates two separate asteroids in orbit about the sun. Systems with positive free energy will generally have unequal sized components with an elongated primary. If the two components have sizes that are closer to each other the free energy can be negative, yet the system may still be unstable. In this situation the proto-binary cannot form a stable binary system without dissipating large amounts of energy. It is more likely that the two components will reimpact or reconfigure themselves until the YORP coefficient becomes negative and starts to decrease the system's rotation rate. This class of asteroid forms a contact binary structure, such as has been frequently observed among the NEO population. The final situation has a negative free energy with the orbital system being stable. These systems have more spheroidal primaries with small, possibly elongate, secondaries. The 1999 KW4 binary system falls into this category and forms a stable binary system if the smaller body were fissioned from the primary. Once such a stable binary system is formed it is subject to other dynamical effects which can cause it to expand and evolve in time.