How binaries color themselves green, and other just-so stories

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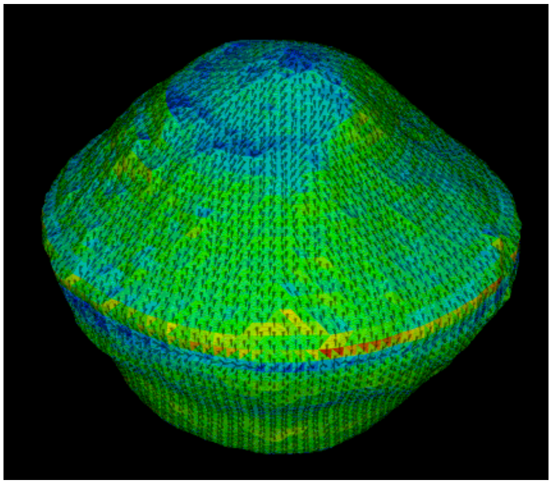
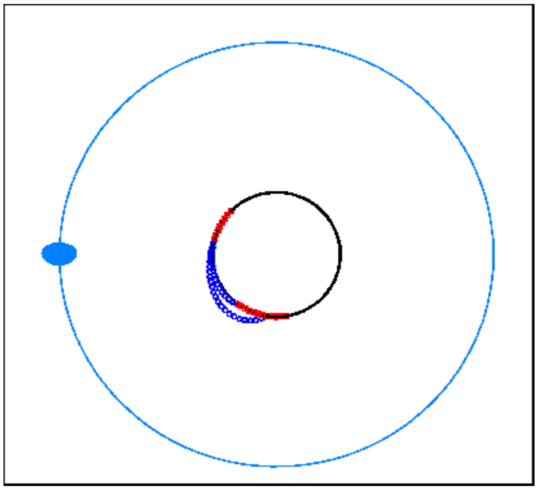


In the recent *Science* papers by Ostro et al. and Scheeres et al., the asteroid (66391) 1999 KW4 is remarkable in the cover illustration in being almost entirely a constant shade of green, where the color coding represents the surface slope, green being in the range of 30-35°. Furthermore, the slopes are almost uniformly in the direction of the equator, as can be seen in the figure to the right, copied from the cover of *Science*. The explanation appears to be that as KW4 is spun up by YORP, the local slope increases to the critical angle for land-sliding, which moves material toward the equator and reestablishes an equilibrium with the average slope of the surface being the angle of repose, which for most dry loose material is around 30-35°. The "top" shape is essentially the figure of quasi-equilibrium of a body that is spinning at a rate that is critical at the equator (gravity = centrifugal force), and has a constant slope at other latitudes, except for the poles, which would be pointed otherwise, and the equator, where slope must pass through zero. Indeed, the detailed shape of the figure allows us to infer the critical angle of slide of the regolith.



A second remarkable feature of 1999 KW4 is the extremely regular equatorial band, which is within about 1% of cancellation of gravity by centrifugal force. I suggest that this equilibrium is established by tidal forces from the satellite moving regolith around the equator. I have computed the motion of material drawn along and even levitated off the surface by the satellite for the case where the tidal force is nearly equal to the imbalance between gravity and centrifugal force on the primary. The figure to the right shows example trajectories of material levitated off the surface briefly as the primary spins below the satellite (the vertical scale is exaggerated several hundred times; rotation is counterclockwise; red is dragging along the surface, blue is levitated; two different ratios of tide to gravitational imbalance are shown). Clearly such mass motion will dissipate energy and transfer angular momentum from the primary to the secondary very quickly compared to elastic tidal friction, and presumably maintains the balance of spin rate between YORP and the critical rate at which such mass flow occurs.

Both of the processes described here will tend to regularize the figure of the primary and eventually shut down the process of YORP evolution. It is especially noteworthy that the very regular equatorial band is a nearly ubiquitous feature of small asynchronous binaries, as revealed by their radar delay-Doppler images and low lightcurve amplitude, as is the tendency to near-critical spin rate, revealed by the very short rotation periods. Thus, I offer this as a "just-so story" of the mode of origin and evolution of most, or maybe all, small asynchronous binaries.