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Building the Ridge of Iapetus: Modeling an In-Falling Ring

K. J. Walsh (1), H. F. Levison (1), D. C. Richardson (2), S. R. Schwartz (2,3)
(1) Southwest Research Institute, Boulder, Colorado, USA, (2) University of Maryland, College Park, MD, USA, (3) University of Nice-Sophia Antipolis, CNRS, Observatoire de la Côte d'Azur, Nice, France (kwalsh@boulder.swri.edu)

Abstract

The ridge on Iapetus is a puzzling feature – up to 15 km tall and 100's of km wide; it is challenging to reconcile with the global history of Iapetus. The most commonly proposed exogenic cause of this feature is the build up of in-falling material from a ring, or disk, of orbiting material [1, 2]. However no detailed modeling exists for which a comparison can be made against the known features of the Iapetan ridge. The constraining features of the Iapetan ridge are: general dimensions, morphology/slopes, possibility for incomplete coverage and some localised cases of parallel ridges or tracks.

We present granular mechanics simulations of ridge growth from an in-falling ring of debris. The parameters that we have explored are tangential/normal velocity ratios for in-falling debris, in-falling ring thickness (inclination), and the effects of pre-existing terrain and/or global shape inequalities.

1. Introduction: Ridge Properties

The first hints of significant equatorial topography on Iapetus came from Voyager 2 imaging. Analysis of limb data pointed to a massive mountain-like structure with heights up to 25 km [3]. These were identified in the Cassini Regio (the dark leading side) between the longitudes of 180 W and 200 W.

The most significant imaging of the equatorial ridge was done by the Cassini spacecraft during a flyby on 31 December 2004. The dark, leading side, was reported to have an equatorial ridge up to 20 km in height [4]. Fig. 6 of that work estimates that the ridge follows a line of latitude ∼2° South from 40° West to 150° West, a distance of 1400 km (Fig 6a was taken from a mosaic of images N1483151512, N1483152862, N1483152937, and N1483153026). Some portion of the peaks are observed at 190 deg West and also 205° West (from image N1476993421, and N1476735994 as found in Fig 6b,c of Porco et al. 2005). Image D finds peaks extending from 185° West to 210° West (Fig 6d or image N1476575655).

Given the current observations, with confirmed existence of the ridge spanning the entire well-observed leading-side hemisphere [4, 5], the leading-side limb [3] and also the trailing-side [5] it is safe to assume that this feature is indeed global. Overall, to summarize the observations and construct a list of target constraints for this modeling effort we find,

1. The ridge is global. It appears to encircle almost the entire world, though there are significant regions where it has seemingly been removed or did not exist.
2. The ridge exhibits triangular and trapezoidal shapes in relative proximity to each other. Profiles r1 to r5 from Giese et al. (2008) show this evolution quite clearly, with changes in the bulk morphology and the slopes along the sides.
3. The ridge appears grooved in places of its greatest width. At the greatest width of the flat-topped peak there are clearly defined ridges or grooves in the ridge itself (see Fig. 3 of Giese et al. 2008).

2. Origin from an in-falling Ring

An important consideration for our model setup is the origin of the in-falling material. Following previous work, an in-falling ring would impact the surface with almost entirely tangential velocities [1, 2]. The magnitude of these velocities would be a function of the rotation rate of Iapetus: with a 16 h rotation the velocities are only ∼ 300 m/s.

Exactly how dynamically cold the disk of in-falling material would be is an open question. A ring with near-zero inclination would impact very precisely in the same plane, with the width of individual particles determining the width of the impact zone. However, any inclination would widen the impact zone, possibly changing the morphology of the building ridge. Given the varied morphological features mentioned above, we need to explore a range of possible ring scenarios.

3. Modeling Efforts

We use `pkdgrav`, an N-body hierarchical tree code modified to handle interactions between discrete spherical particles, to model the particle interactions during and after their impact onto the surface of Iapetus. Though the gravitational interaction between particles is not important, `pkdgrav` benefits from a highly parallelized nearest-neighbor finding algorithm to drastically speed-up the collision and particle-particle interaction calculations. Likewise, modeling the entire surface of Iapetus is not feasible, rather we simulate a patch of the surface, 5 km wide, with periodic boundary conditions downrange. At $z = 0$, there is a wall (horizontal plane), which adopts similar frictional and resitutional properties as the particles interacting with it [6].

For particle-particle and particle-wall interactions we explore two different code implementations. First, the standard mode of simulation with `pkdgrav` is a “Hard-Sphere” method in which collisions are detected in advance and resolved in temporal order. Particles do not overlap, and there are no resting contact forces (so particles in aggregates have a very small amount of vibrational energy).

The second simulation method is to use the “Soft-Sphere” implementation of `pkdgrav` in which particles are allowed to overlap, generating contact forces that resolve the interparticle collisions (see Schwartz et al. 2011 in this publication [7]). This is ideal for modeling dense granular flows.

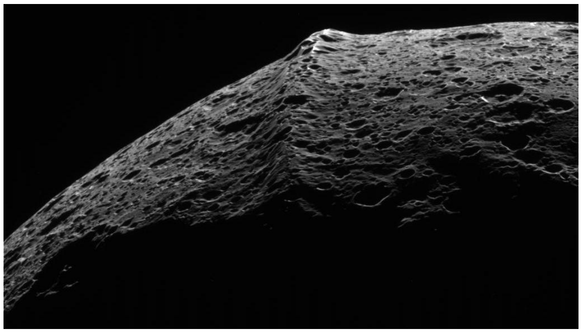

Figure 1: A striking image of the equatorial ridge of Iapetus. Image from the Cassini-Huygens mission (a joint mission of NASA, ESA and ASI).

4. Summary and Conclusions

We present our efforts to model the Iapetan equatorial ridge as a build-up from an in-falling ring of material. We have attempted to match not just the bulk shape of the ring, but also the distinct features of triangular and trapezoidal shapes and also the parallel ridges.

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References

[1] Ip, W.-H.: On a ring origin of the equatorial ridge of Iapetus. Geophysical Research Letters 33, 16203, 2006.

[2] Levison, H. F., Walsh, K. J., Barr, A. C., Dones, L.: Ridge Formation and De-Spinning of Iapetus via an Impact-Generated Satellite. Icarus *in press*, 2011.

[3] Denk, T., Matz, K.-D., Roatsch, T., Wolf, U., Wagner, R. J., Neukum, G., Jaumann, R.: Iapetus (1): Size, Topography, Surface Structures, Craters. Lunar and Planetary Institute Science Conference Abstracts 31, 1596, 2000.

[4] Porco, C. C., and 34 colleagues.: Cassini Imaging Science: Initial Results on Phoebe and Iapetus. Science 307, 1237-1242, 2005.

[5] Giese, B., Denk, T., Neukum, G., Roatsch, T., Helfenstein, P., Thomas, P. C., Turtle, E. P., McEwen, A., Porco, C. C.: The topography of Iapetus’ leading side. Icarus 193, 359-371, 2008.

[6] Richardson, D. C., Walsh, K. J., Murdoch, N., Michel, P.: Numerical simulations of granular dynamics: I. Hard-sphere discrete element method and tests. Icarus 212, 427-437, 2011.

[7] Schwartz, S. R., Richardson, D. C., Michel, P., Walsh, K. W. 2011.: Modeling the granular surface and interior of small bodies using the Soft-Sphere Discrete Element Method: implementation in the N-body code pkdgrav and tests. DPS-EPSC 2011, 2-7 October 2011, Nantes, France, 2011.