SHAPES OF THE SATURNIAN ICY SATELLITES.

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Introduction Shapes of satellites and planets can reveal both surface processes and internal structures. The overall figure of an object may indicate relaxation to a gravitational equilibrium shape; and with knowledge of the mean density, departure from a homogeneous interior may be detected and quantified. The overall shapes are found by measurement of limb positions in the ISS images using techniques described in [1]. The high resolution images and multiple views mean that most of the uncertainty in the shapes derives from the topography: the deviations from perfect ellipsoidal outlines.

Dimensions of six of the Saturnian satellites are given in Table 1. For comparison, we include values of (a-c) if the object were homogeneous material of the measured mean density.

An equilibrium ellipsoid has a specific relation among the axes (a, b, c): f=(b-c)/(a-c)=0.25 (The values of f drops slightly for rapidly spinning satellites such as Mimas and Enceladus, ~ 0.23). For a particular spin rate, a homogeneous, relaxed object has an (a-c) directly proportional to the mean density and mean radius. Objects with central mass concentrations have a reduced (a-c) compared to the homogeneous case. Numerical 2-layer models allow us to evaluate the supported topography for the various shapes and different internal configurations.

Results:

Mimas: Mimas departs from an ideal relaxed figure by 2.7 km, and has an (a-c) nearly 3 km less than a homogeneous body would if fully relaxed. If homogeneous, its global form supports 2 km of topography. Standard two-layer models, with a mantle of water ice, and core of varying density above 2500 kg m^{-3} can only reduce the supported topography to 1.5 km because the shape is non-equilibrium.

Enceladus: A homogeneous model of Enceladus supports 0.50 km of relief; the best allowable f reduces this to 0.36 km. A model with density 3000 kg m^{-3} core supports 1.2 km of topography. Something close to a homogeneous interior is the best model for Enceladus [2]. Thin ice crusts of 10-20 km over interiors of homogeneous material 1700-1800 kg m^{-3} support ~ 0.5 km topography. If Enceladus were differentiated with a density 3000 kg m^{-3} core, the current shape might be frozen from formation at 88% of the current distance from Saturn, although dynamical expectations limit outward evolution from ~95% [3].

Tethys, Dione, Rhea: These satellites are all consistent with homogeneous interiors, although the uncertainties of their shapes makes it impossible to eliminate some amount of central mass concentration.

Iapetus: Cassini images show Iapetus is an oblate spheroid, with a difference in equatorial and polar axes of 34.5 km, confirming a non-spherical shape reported by [4]. Its synchronous spin period of 79 d would produce an axial difference of only ~ 10 m for an object of its mean density. The shape is consistent with having formed at a spin period of ~17 hr. The despining and preservation of a frozen-in shape present interesting problems in thermal history [5].

Because Iapetus has not relaxed globally, that is, it records shorter wavelenth topography on what was once a relaxed form, its limb roughness may calibrate the relaxation state of topography on other satellites, which all have limb profiles 3 to 10 times smoother than Iapetus (Fig. 1). Thus, Mimas has relaxed at scales smaller than its radius, but globally supports at least 1.5 km of topography. Non-radially symmetric inhomogeneities may be required in this satellite.

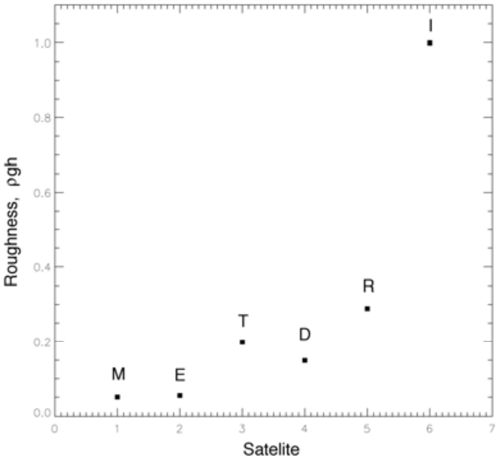

Figure 1. Roughness of limbs of icy satellites. Values are the rms residuals in km to the overall shape fit, scaled by satellite gravitational acceleration and assuming the same density material in the topography on all satellites, and scaled to Iapetus. Iapetus' roughness is 4.1 km; Enceladus' is 0.44 km.

References: [1] Thomas, P. C. et al. 1998. *Icarus* **135**, 175-180. [2] Porco, C. et al. 2006. *Science*, submitted. [3] Dermott, S. F. and P. Thomas 1994. *Icarus* **109,** 241-257. [4] Denk, T., et al. 2000. LPSC XXX1, abstract #1596. [5] Castillo, J. C., et al. 2005. *Bull. Amer. Astron. Soc.* **37,** 705. [6] Jacobson, R. A., et al. 2006. for submission to *Science.*

Table 1 Satellite shapes

Satellite	a	b	c	mean radius	ρ, kg m^{-3}	a-c, km	a-c h	im	data
Mimas	207.4	197.2	190.7	198.3±0.6	1148±11	16.7±0.6	19.5	16	9832
Enceladus	256.6	251.4	248.3	252.1±0.2	1608±5	8.3±0.6	8.0	23	15017
Tethys	540.4	531.1	527.5	533.0±1.0	973±6	12.9±1.8	14.7	7	3003
Dione	563.8	561.0	560.3	561.6±0.5	1477±4	3.5±1.2	4.9	14	8184
Rhea	767.6	762.5	763.2	764.4±1.1	1233±5	4.4±2.7	2.9	17	12572
Iapetus	747.1	749.0	712.6	736.0±2.0	1081±18	34.5±3.7	0.01	31	8906

a, b, c in km.; (a-c) h is predicted (a-c) for homogeneous model. Here we use a , b, c to denote the Saturn-facing, orbit-facing, and polar radii. Except for Iapetus, longest dimension is within observational limits of Saturn-facing. im: images used; data: data points; density determined from masses reported in [6].