NEW STEREOPHOTOCLINOMETRY SHAPE MODELS FOR IRREGULARLY SHAPED SATURNIAN SATELLITES.
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Introduction: The Cassini mission returned unprecedented volumes of valuable data on the Saturn system, including its moons. Titan and Enceladus were the subjects of many dedicated flybys and received a tremendous amount of attention [e.g., 1,2]. Other regularly shaped satellites (Mimas, Tethys, Dione, Rhea, and Iapetus) were also well-studied [e.g., 3,4].

Cassini also acquired moderate- to high-resolution images of several of the smaller, irregularly shaped satellites, including Atlas, Calypso, Epimetheus, Helene, Hyperion, Janus, Pan, Pandora, Phoebe, Prometheus, and Telesto. These irregularly shaped satellites hold additional clues to the history and evolution of the saturnian system and can be used to better understand small bodies. Differences and similarities between moons with similar orbits (e.g., Janus and Epimetheus; Calypso and Telesto) should hold clues to the origins, migration, or exogenic contamination of these bodies [e.g., 5,6].

The irregular shapes of these moons, however, pose challenges to analysis. Visualizing data and mapping features on irregular bodies is difficult, and 2D map projections severely distort spatial relationships and size. These challenges can be overcome by visualizing the data on an accurate shape model. Consequently, we are developing updated or new shape models for several irregularly shaped saturnian satellites using Cassini ISS images and stereophotoclinometry (SPC). In addition, we are adding ISS data to the publically available Small Body Mapping Tool [7,8], which will allow members of the community to visualize and analyze Cassini data directly on the shape models once the shapes are released.

Shape modeling: SPC has been used successfully to develop high-resolution shape models of a variety of small bodies, including Eros [9], Itokawa [10], Phobos [11], Phoebe [12], Lutetia [13], and comet 67/P Churyumov-Gerasimenko [14], among others. The method is also integral to the altimetry and shape modeling efforts for the OSIRIS-REx [15] and Hayabusa2 missions.

SPC uses images obtained across a range of viewing geometries, combined with knowledge of the spacecraft's location and camera pointing, to generate a detailed shape model of the object of interest [10]. In the workflow we are using, images are first registered to a limb-based shape model (Fig. 1). This shape is then tiled with maplets tied to landmarks viewed in multiple images with different viewing geometries. Monte Carlo integration allows the determination of local terrain heights relative to the landmarks. Constraints from overlapping or lower-resolution maplets, limbs, shadows, and geometric stereo condition the solution. SPC maplets are then combined to determine the global topography model for the body (Fig. 2).

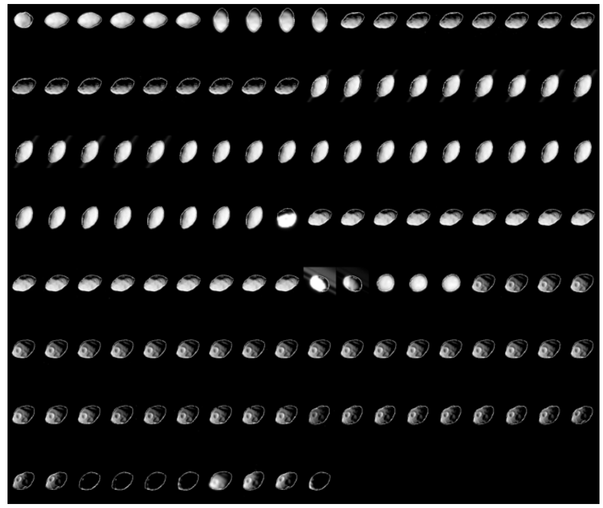

Figure 1. Cassini ISS images of the moon Pandora registered to a low-degree, limb-based Pandora shape model. Thin white lines around each image indicate the extent of the limb-based shape model. Pandora has a mean radius of ~41 km.

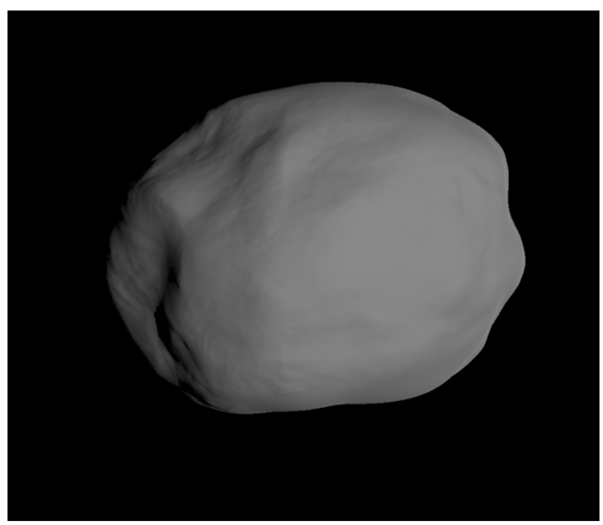

Figure 2. Preliminary, low-resolution global shape model for Helene (as of December 2017) generated by tiling the body with maplets in 15° increments of latitude and longitude (7.2 km maplets, 120 m ground sample distance). The model will improve significantly as we tile with higher-resolution maplets. Helene should support maplets with a ground sample distance of ~15 m in areas covered by the highest resolution images.

We are updating an existing SPC model developed by Bob Gaskell for Phoebe. Models of Atlas, Calypso, Epimetheus, Helene, Hyperion, Janus, Pan, Pandora, Prometheus, and Telesto are new. In all cases, we use WAC and NAC images acquired by the Cassini ISS from 2004 through the end of mission in late 2017. Although coverage varies from body to body, many moons have near-global coverage for images in which the body is 20 pixels or more across the smallest dimension of the moon (Fig. 3). Images with a coarser pixel scale are ill-suited for this application. All bodies have high-resolution ISS coverage across portions of their surfaces. Completed shape models will be archived in the PDS.

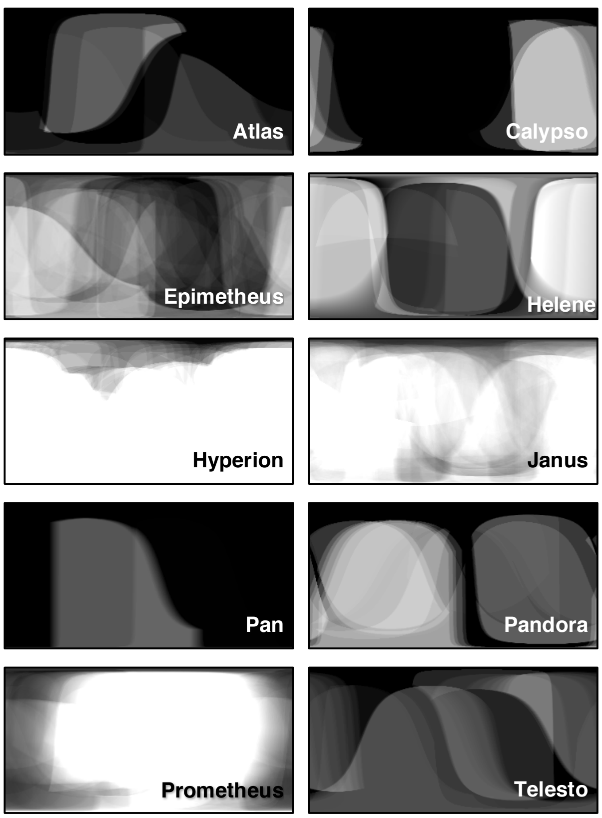

Figure 3. Simple cylindrical maps showing regions of each moon imaged by the Cassini ISS at or better than the pixel scale needed for the moon to appear 20 pixels across. Many moons have near-global coverage, although some (e.g., Atlas, Calypso, Pan) have only regional coverage. Areas that appear brighter were covered by multiple imaging sequences. Hyperion, Janus, and Prometheus, in particular, have large areas of their surfaces that were covered by many Cassini flybys.

Future Work: The new shapes will permit investigations of surface processes with co-registered images on higher-resolution shape models than have been previously available. In areas imaged at high resolution, the global SPC models will improve on the resolution of existing shape models [16] by an order of magnitude.

In addition, we are adding new functionality to the free, publically available Small Body Mapping Tool (sbmt.jhuapl.edu) so that Cassini ISS data can be searched, loaded, and projected onto the new shape models. The Tool will also include geophysical maps (elevation, slopes, gravity) and geometry backplanes to the ISS images. Once users find the data they need using the SBMT's interactive search capabilities, built-in tools allow the user to do many analyses in the SBMT (Fig. 4). Alternatively, users can export the data for analysis in another program.

References: [1] Porco et al. (2005) *Nature*, 434, 159–168. [2] Porco et al. (2006) *Science,* 311, 1393–1401. [3] Thomas et al. (2007) *Icarus,* 190, 573–584. [4] Roatsch et al. (2013) *Planet. Sp. Sci.,* 77, 118–125. [5] Filacchione et al. (2010) *Icarus,* 206, 507–523. [6] Filacchione et al. (2012) *Icarus*, 220, 1064–1096. [7] Kahn et al. (2011) *LPS42*, ab. 1618. [8] Ernst et al. (2018) *LPS49,* ab. 1043. [9] Gaskell (2008) Gaskell Eros Shape Model V1.0, PDS. [10] Gaskell et al. (2008) *MAPS,* 43, 1049–1061. [11] Gaskell (2011) Phobos Shape Model V1.0, PDS. [12] Gaskell (2011) Phoebe Shape Model V1.0, PDS. [13] Farnham (2013) Shape Model of Asteroid 21 Lutetia V1.0, PDS. [14] Jorda et al. (2015) SPC SHAP2 Cartesian plate model for comet 67P/C V1.0, PDS. [15] Weirich et al. (2017) *LPS48,* ab. 1700. [16] Thomas et al. (2013) *Icarus*, 226, 999–1019.

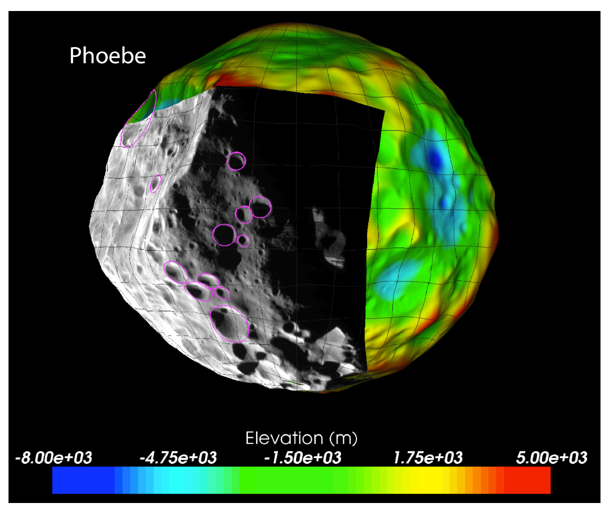

Figure 4. Screen capture from the Small Body Mapping Tool (SBMT). A Cassini ISS image of Phoebe has been draped onto the existing Gaskell Phoebe shape model [12]. The shape has been colored according to elevation. A handful of craters have been mapped using the "structures" tab in the SBMT. The locations, dimensions, and geophysical data associated with mapped features (craters, lineaments, etc.) are saved as human-readable XML or ASCII files that can be easily imported into other codes for additional analysis.