EPSC Abstracts
Vol. 6, EPSC-DPS2011-416, 2011
EPSC-DPS Joint Meeting 2011

Shape reconstruction of irregular bodies with multiple complementary data sources

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Irregularly shaped bodies with at most partial in situ data are a particular challenge for shape reconstruction and mapping. We have created an inversion algorithm and software package for complementary data sources, with which it is possible to create shape and spin models with feature details even when only groundbased data are available. The procedure uses photometry, adaptive optics or other images, occultation timings, and interferometry as main data sources, and we are extending it to include range-Doppler radar and thermal infrared data as well.

The data sources are described as generalized projections in various observable spaces [2], which allows their uniform handling with essentially the same techniques, making the addition of new data sources inexpensive in terms of computation time or software development. We present a generally applicable shape support that can be automatically used for all surface types, including strongly nonconvex or non-starlike shapes. New models of Kleopatra (from photometry, adaptive optics, and interferometry) and Hermione are examples of this approach. When using adaptive optics images, the main information from these is extracted from the limb and terminator contours that can be determined much more accurately than the image pixel brightnesses that inevitably contain large errors for most targets. We have shown that the contours yield a wealth of information independent of the scattering properties of the surface [3]. Their use also facilitates a very fast and robustly converging algorithm.

An important concept in the inversion is the optimal weighting of the various data modes. We have developed a mathematicallly rigorous scheme for this purpose. The resulting maximum compatibility estimate [3], a multimodal generalization of the maximum likelihood estimate, ensures that the actual information content of each source is properly taken into account, and that the resolution scale of the ensuing model can be reliably estimated.

We have applied our procedure to several asteroids, and the ground truth from the Rosetta/Lutetia flyby confirmed the ability of the approach to recover shape details [1] (see also Carry et al., this meeting). We have created a general flyby-version of the procedure to construct full models of planetary targets for which probe images are only available of a part of the surface (a typical setup for many planetary missions). We have successfully combined flyby images with photometry (Steins [4]) and adaptive optics images (Lutetia); the portion of the surface accurately determined by the flyby constrains the shape solution of the "dark side" efficiently.

References

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