The preliminary shape of Ceres

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Abstract

Methods have been developed [1, 2] to derive the global shape of a celestial body quickly with the help of limb images taken by spacecraft. Topographic profiles are found by applying a contrast-based search along the limb. By minimizing height differences at crossover locations between the individual limb profiles their locations are improved and a global network is created. We used images taken by the Dawn spacecraft during the Ceres approach from February to May of 2015 to derive the shape of the dwarf planet. 656 images from the OPNAV 4, OPNAV 6, OPNAV 7, and RC 3 phases have been examined yielding a network of topographic profiles offering an almost global coverage. By fitting a tri-axial ellipsoid to the data we found Ceres to be an oblate spheroid with axes significantly smaller than previously estimated [3].

1. Introduction

Several methods can be used to determine the global shape of celestial bodies, e.g. laser altimetry, stereo-photogrammetry, and stereo-photoclinometry. Another well-known procedure is the analysis of limb images [4].

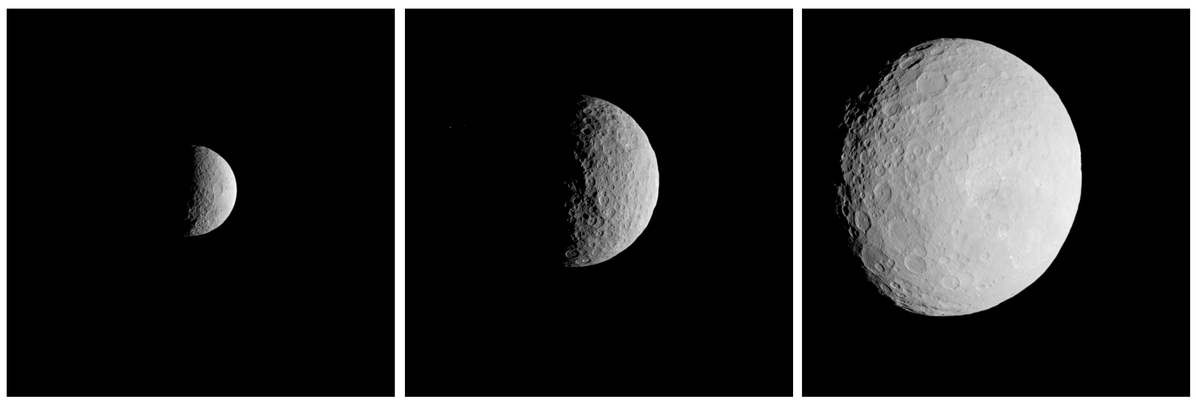

Fig. 1: Ceres limb images f2_478163506_1 (left, OPNAV 4), f2_482356946_1 (center OPNAV 7), and f2_484006570_1 (right, RC3), taken between February 25, 2015 and May 4, 2015.

2. Image data

We used 644 Dawn FC limb images from the OPNAV 4, OPNAV 6, OPNAV 7, and RC3 mission phases from February to May of 2015 (Fig. 1, Table 1) in a combined analysis. RC3 provides data from full rotational periods while the OPNAV limb profiles cover areas between 270°E and 120°E. The whole set of profiles spans from pole to pole offering an almost global coverage of Ceres' surface (Fig. 2). Both polar regions are comparably sparsely covered. To avoid bias towards the clustered OPNAV data, only selected profiles of these are included in the analysis ensuring a more or less uniformly built network.

Mission pha	Image count	Distance [km]	Resolution [km/px]
OPNAV 4	5	40,000	3.8
OPNAV 6	4	34,000	3.1
OPNAV 7	3	23,000	2.1
RC3	644	14,000	1.3

Table 1: Ceres limb images and their respective resolutions.

3. Method

Topographic profiles are found by applying a contrast-based search along the limb. Their locations on a reference sphere are improved by adjusting the exterior camera orientation parameters, i.e. attitude angles, for each limb image using height differences at intersections between the profiles in a least-squares-fit. The selected profiles provide almost 51,000 intersections, with the vast majority residing in the northern and southern mid-latitudes.

References

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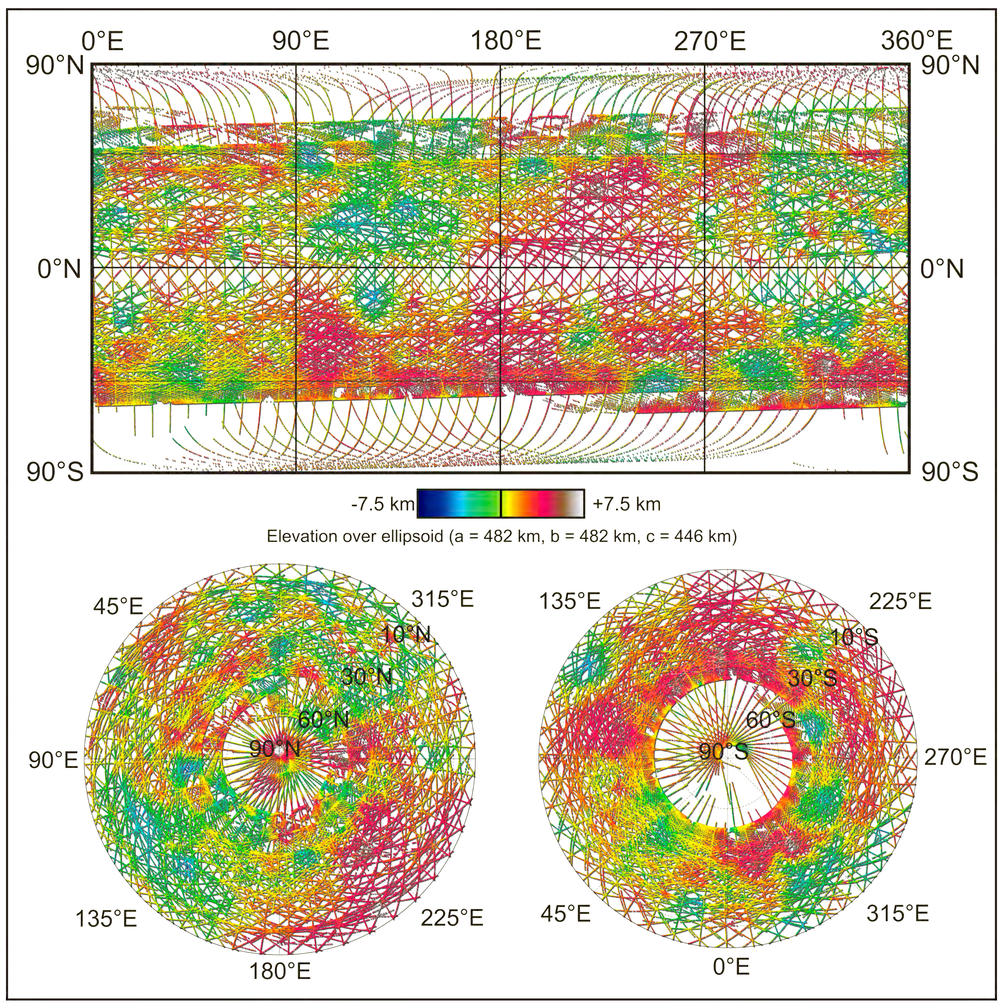

Fig. 2: Adjusted Ceres limb profiles in global simple cylindrical projection (top) and Lambert azimuthal projection for the northern (lower left) and southern (lower right) hemisphere.

4. Results

We have fitted a tri-axial ellipsoid with axes of a = 483.3 ± 0.5 km, b = 481.2 ± 0.5, and c = 447.1 ± 0.3 km to the ca. 260,000 adjusted object points. The difference between the semi-major axes a and b of 2.1 km is small, therefore we can describe Ceres as an oblate spheroid with a significant polar flattening of f = 1/13. The resolution of the network is good enough to resolve large-scale (> 100 km) topographic features, e.g. large basins (Fig. 3).

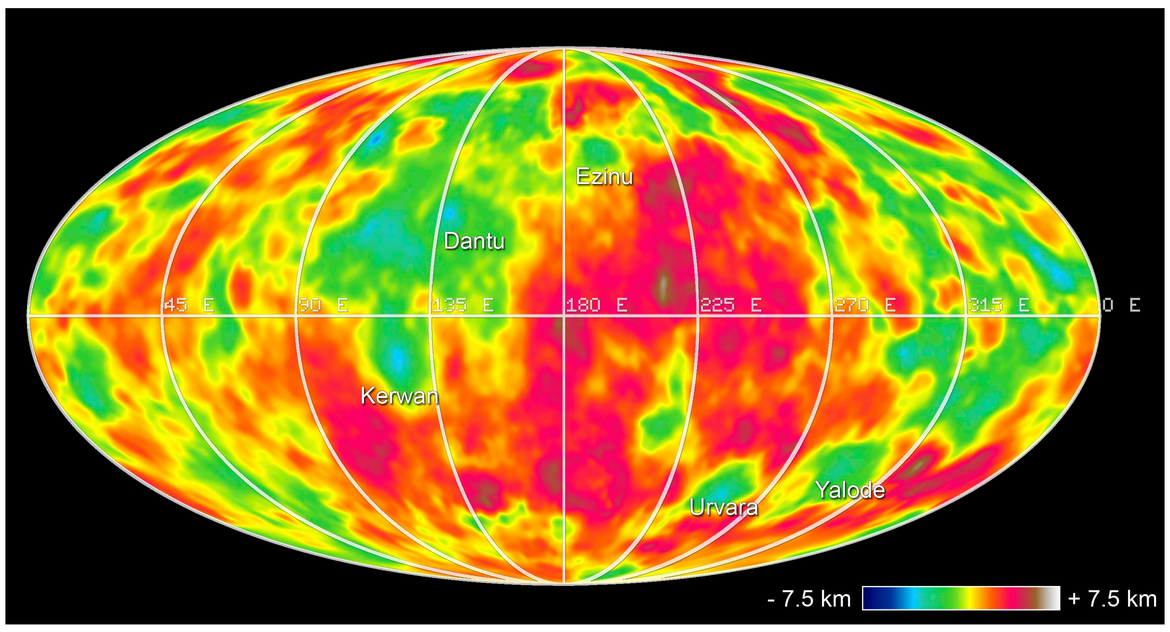

Fig. 3: Interpolated digital terrain model in Mollweide projection. Heights are over a biaxial ellipsoid (*a* = 482 km, *b* = 446 km).

	Limb	HST [3]
semi-major axis a	483.3 ± 0.5 km	487.3 ± 1.8 km
semi-major axis b	481.2 ± 0.5 km	487.3 ± 1.8 km
semi-minor axis c	447.1 ± 0.3 km	454.7 ± 1.6 km
body long axis at	224.6 ± 10.6 °E	

Table 2: Ceres shape parameters derived from the adjusted limb profiles compared to earlier results using Hubble Space Telescope (HST) images [3].

5. Summary and Outlook

We have derived the shape of Ceres from Dawn FC limb images. Ceres is an oblate spheroid with a significant polar flattening. Large-scale topography is visible in the limb profiles.

The introduction of additional observations from subsequent mission phases will help to further stabilize the network and refine the results. Images with higher resolutions will enable us to identify and measure topographic features at the limb.