TOPOGRAPHY OF THREE LOCALITIES ON THE MOON FROM COMBINED CLEMENTINE AND HUBBLE SPACE TELESCOPE IMAGES. A. N. Opanasenko[1], Yu. G. Shkuratov[1], N. V. Opanasenko[1], [1]Astronomical Institute, Kharkov National University, 35 Sumskaya St., Kharkov, 61022, Ukraine, opanasenko@astron.kharkov.ua.

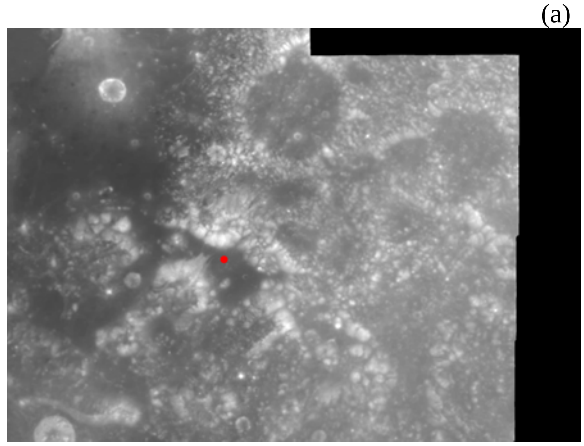
We present topographic maps of the Moon for localities imaged by the Hubble Space Telescope in 2005. Topography was derived by the photogrammetric method from HST and Clementine image pairs.

Introduction: Knowing kilometer and sub-kilometer-scale topography of the lunar surface is essential for a variety of scientific studies. The present-day knowledge of the lunar topography is surprisingly poor. Apollo era printed topographic maps have been produced by manual analysis of shadows on astronomical images; for some localities, higher resolution topographic maps were obtained from manual analysis of orbital images taken from different directions and considered as stereopairs. Although still useful even for quantitative analysis (e.g., [1]), these old maps have very low absolute vertical accuracy and inherently inhomogeneous vertical precision. Accurate measurements of the local planetary radius by the laser altimeter onboard Lunar Prospector mission [2] are too sparsely spaced; they are good only for studies of the global figure and regional-scale features. Clementine images taken at different looking angles were used in [3] to derive local topography through automated photogrammetric processing. Here we report on our photogrammetric derivation of topography from combined Clementine and Hubble Space Telescope (HST) images of some localities on the Moon.

Data and processing: HST images of three targets on the Moon (Apollo 15 and 17 landing sites and Aristarchus crater and plateau) were obtained in August 2005 with ACS/HRC camera in 4 filters, 5 individual (~ 1 Mpix) images for each target in each filter [4]. Viewing geometry was defined by mutual location of the HST on its orbit and the Moon and was close to view from the Earth. We used images in a red filter F658N. UVVIS camera onboard Clementine spacecraft has produced a global coverage with small nadir-looking images in 5 filters; we used red filter B. Resolution of Clementine and HST images is similar (about 100 m; somewhat better for HST). We used the difference in viewing geometry between HST and Clementine images to measure parallactic shifts and derive surface topography. Illumination conditions for both image sets were rather similar (low or moderately low phase angles), which facilitated topography derivation.

We projected all individual images into the simple cylindrical projection, and then made mosaics of Clementine and HST images for the HST-observed sites. For our processing, it is essential that the mosaics are seamless; because of this, we did not use the global Clementine mosaic available from PDS; we made our local mosaics with seamless adjustment of adjacent images. Examples of these source mosaics for Apollo-17 landing site are shown in Fig. 1.

(a)



(b)

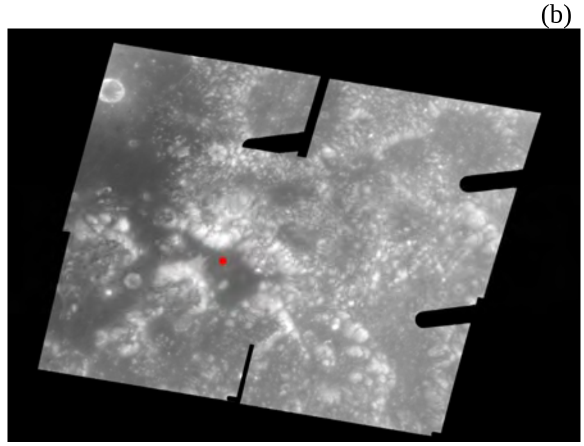


Fig. 1. The Clementine 750 nm (a) and HST 658 nm (b) mosaics of the region of the Apollo 17 landing site (red marker).

To derive surface topography we measured parallactic shifts between HST and Clementine mosaics by maximizing correlation function between them calculated a small circular sliding window with soft boundaries. Knowing a pair of viewing directions for each position of the sliding window, the measured shifts can be recalculated into elevations with respect to an arbitrary datum. Accuracy of Clementine and HST pointing knowledge is too low to obtain absolute elevation with respect to the lunar center of mass.

To reach reasonable (tens of meters) vertical precision, the parallactic shifts should be measured with subpixel accuracy, which demands appreciable size of the window for matching. On the other hand, the use of larger window decreases spatial resolution of the elevation model. In principle, the balance of the vertical precision and spatial resolution dictates the choice of the window size. In practice, however, another factor limits the window size: some parts of the scenes are rather featureless, and images are quite noisy; because of this, maximizing correlation in a small window may give a false result due to matching the noise patterns rather than surface features. Such false parallactic shifts can be easily filtered out, even if their proportion is rather high, however, this would lead to strongly nonuniform spatial resolution. We chose the window radius of 10 pixels, which gave reasonable proportion of false matches, and the step between neighboring windows of 5 pixels. We applied an original heuristic algorithm to identify false matches, remove them, and "cure" the gaps in the elevation model. In this way we mapped elevation.

Results: We illustrate our results (see figures) with one of the three HST targets, namely, Apollo-17 landing site. For orientation, the landing site itself is shown with a red dot in all images. Fig. 1 shows the source mosaics, Fig. 2 presents the elevation map. Highland massifs rise about 2 km above the valley floor. Fig. 3 compares our map with USGS 1:50,000 map [5] digitized in [1]; very good qualitative agreement is seen. Our map has lower apparent resolution because it misses some small details seen in the manually made USGS map, e.g. a few small craters on the valley floor. Fig. 4 shows simulated oblique views of the shaded topography (the Lambertian scattering indicatrix was used to generate this image). Fig. 5 shows the same oblique view draped with the image.

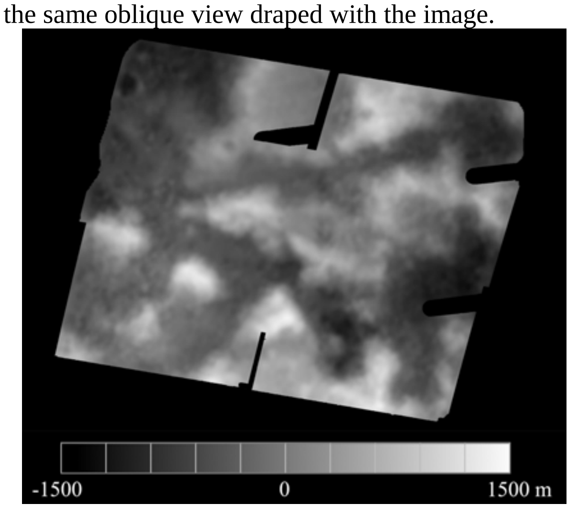


Fig. 2. Map of elevations; brighter shades denote higher elevations.

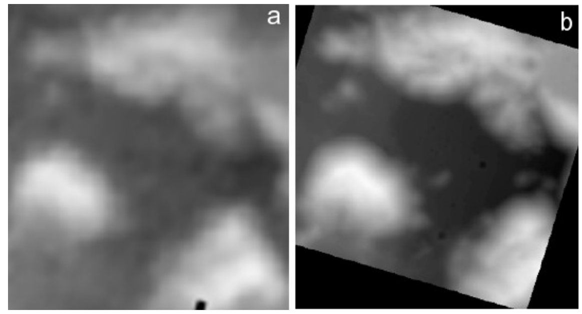


Fig. 3. (a) Fragment of the elevation map shown in Fig. 2; (b) Digitized topographic map [5] taken from [1]. brighter shades denote higher elevations.

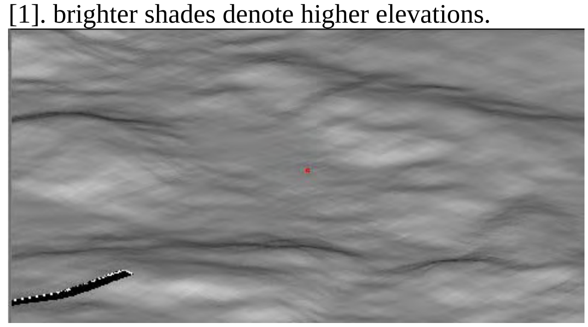


Fig. 4. Perspective view of Taurus-Littrow valley. Simulated shaded topography.

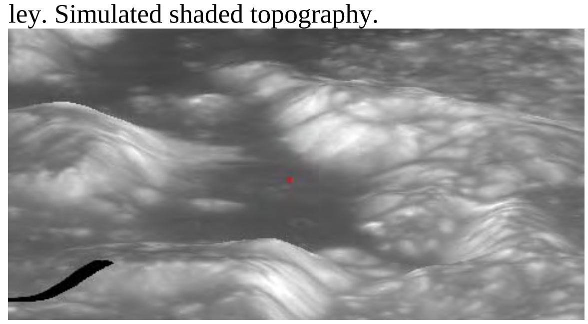


Fig. 5. Simulated perspective view of Taurus-Littrow image.

Conclusions: We showed that the pairs of Clementine/UVVIS and HST/ACS/HRC images can be effectively used to reconstruct topography of the lunar surface with the resolution of hundreds of meters and vertical precision of tens of meters. Obtained digital elevation models can be useful for photometric corrections in spectrophtometric studies, like in [1] and assist geological studies. Individual parallactic measurements of selected features potentially can provide better accuracy and resolution and can be effectively applied to measure selected slopes in the localities.

References: [1] Robinson M., Jolliff B. (2002) *JGR*, *107*, doi:10.1029/2001JE001614. [2] Smith, D. E. et al. (1997) *JGR 102*, 1591. [3] Oberst J., et al. (1996) *Planet. Space Sci.*, *44*, 1123–1133. [4] Garvin J., et al. (2006) *LPSC 37*, #2100. [5] USGS. Preliminary topographic map of part of the Littrow region of the Moon, scale 1:50,000, Flagstaff, Ariz., March 1972.