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Fourier-based analysis of lineament structures on the Hathor cliff of comet 67P

Birko-Katarina Ruzicka (1,2), Matthias Schröter (3), Hermann Boehnhardt (1) and Andreas Pack (2)
(1) Max Planck Institute for Solar System Research, Planets and Comets, Göttingen, Germany (ruzicka@mps.mpg.de)

(2) Georg-August-Universität Göttingen, Geowissenschaftliches Zentrum, Göttingen, Germany

(3) Max Planck Institute for Dynamics and Self-Organization, Dynamics of Complex Fluids, Göttingen, Germany

Abstract

We are studying layering-related lineament structures on the nucleus surface of comet 67P/Churyumov-Gerasimenko ('67P') in order to determine the three-dimensional sub-surface orientation of its layerings. Our previously presented approach [2,3] was limited to linear features with significant curvature, e.g. along hill slopes and the edges of mesas. This excludes its application to the lineaments exposed on the comet's planar cliff faces. We developed a Fourier-based method to measure the orientation and average distance of layer-boundaries in subsections of the Hathor cliff, resulting in a map of layering thicknesses with unprecedented scope and resolution.

1. Motivation

Cliff faces are among the surfaces on comet 67P that are least altered by weathering, which makes them ideal for studying finer details. Space weathering and deposition of dust from airfall have smoothed the morphological features on most other areas of the nucleus surface, but the layering-boundaries remain distinguishable at distances no more than a few meters apart in some parts of the Hathor cliff. The thickness and number of layerings in the cometary nucleus are a key parameter in modeling potential mechanisms of their formation. The modeling could be aided by knowledge of the precise layering thicknesses across the entire Hathor wall, which makes up more than 10% of the small lobe's surface area.

2. Layering thicknesses from FFT

We build on a previous study [1] of brightness variations across a small segment of Hathor and extend it to a detailed analysis of the entire wall, resulting in a map of layering thicknesses at the highest possible resolution. For this, we split the best available view of the cliff into overlapping frames of 100x100 pixels, computed the fast Fourier transform

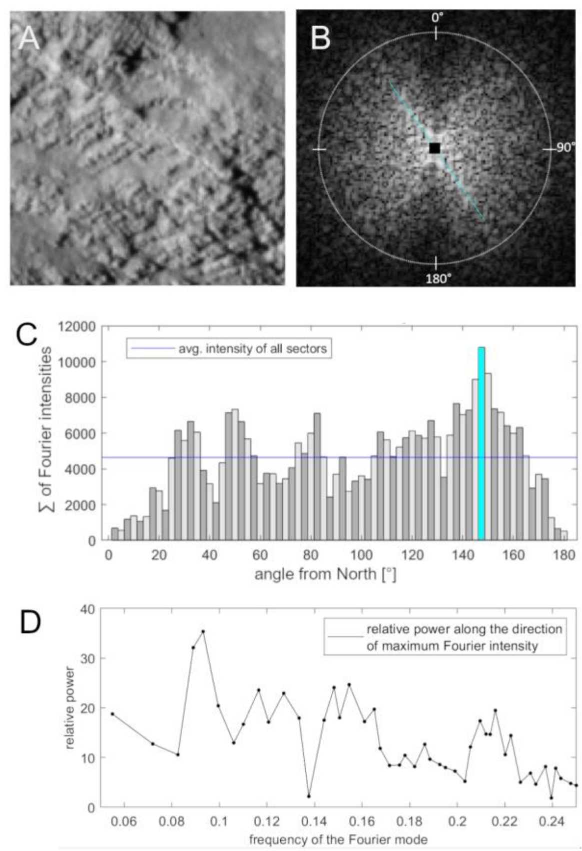

Figure 1: Demonstration of our method on an example image. **A**: Cropped area of the Hathor cliff, showing layering-related lineaments. **B**: Fourier Transform of the image, overlaid with circle used to define sectors. **C**: Cumulative Fourier intensity in each 5°-wide sector of the circle shown in B. Cyan lines mark the direction of max. Fourier intensity in B and C. **D**: Power spectrum along this direction.

(FFT) for each frame, determined the direction of the layerings in the FFT (which is the direction of maximum Fourier intensity for most frames) and determined the most common distance of lineaments from the FFT power spectrum along that direction. Figure 1 illustrates this method with an example image. The direction of maximum Fourier intensity for this image is 147.5° ± 2.5°, the frequency of the Fourier modes along this direction peaks at 0.09, equivalent to a dominant wavelength of 10.9 pixels. Accounting for the spatial resolution of the image as well as the viewing geometry results in a dominant layering thickness of approximately 10 meters. This exemplary result demonstrates that our method is capable of measuring the layering thicknesses on the Hathor cliff at outstanding spatial resolution.

Fourier-based serialized image analysis has several advantages over manual mapping and analysis of the layering-related lineaments: It is considerably faster and infinitely repeatable, can detect features at much smaller scales, and operates at pixel precision instead of relying on a human to draw or click with attention and consistency. Most importantly, it is unbiased with regard to features it classifies as layering-related. We aim to use this property to reduce the impact of confirmation bias and interpreting patterns into noise. Our method, once refined, will be applicable to outcrops of layered materials on all bodies in the Solar System.

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