FOURIER TRANSFORM DE-STRIPING OF LRO LAMP DATA PRODUCTS. A. A. Wirth-Singh[1,2], J.T.S. Cahill[2], and D. Waller[2]. [1]University of Washington (annaw77@uw.edu), [2]Johns Hopkins University Applied Physics Laboratory.

Introduction: The Lunar Reconnaissance Orbiter Lyman-Alpha Mapping Project (LRO LAMP) provides a unique view of the Moon in both global equatorial and polar data products in the far-ultraviolet (FUV) spectrum (<130 nm) [1]. An artifact visible in the global data products consists of vertical striping noise which can obscure faint surface features, such as lunar swirls and crater ejecta [2], which LAMP is uniquely positioned to study.

Various methods of de-striping images have been applied to other data sets, each with particular advantages and disadvantages. The optimal de-striping method for a particular dataset depends on the nature of the striping. These methods include histogram matching [3], frequency component filtering [4-7], and wavelet analysis [8]. In this work, we report our initial examination of frequency component filtering using Fourier transforms applied to the LAMP dataset.

Dataset: LRO LAMP is a push-broom photon-counting spectrometer that detects albedo. During nighttime observations, the LAMP instrument detects interplanetary hydrogen photons which reflect off the lunar surface. Raw photon counts amassed over many orbits are compiled and normalized to produce a complete dataset. Spectral bands between 119 and 125 nm are averaged to reflect starlight and Lyman-alpha skyglow centered at 121.6 nm. The composite map used in this work has a resolution of 32 pixels per degree.

Methods: Variations of frequency component methods have previously been used for planetary data [6-7] and, perhaps more extensively, electron force microscopy data [4-5]. Sometimes, more complicated algorithms are introduced to reduce the possibility of distorting the actual data. In the frequency component analysis, distortions can occur by unintentionally deleting image data which happens to occur at the same frequency as the striping. Due to the periodic, unidirectional nature of the striping in the LAMP data and the lack of similarly described features on the Moon, a frequency component analysis method effectively de-stripes the LAMP dataset, and we demonstrate optimizing this method for the data.

First, the image data is Fourier transformed obtain the power spectrum of the image. When the transform is arranged such that the zero frequency component lies at the origin, the frequency components of the vertical stripes manifest as a horizontal line over the origin. An angular sector including this horizontal line, but excluding the origin, is deleted. This modified transform is then reverse Fourier transformed to obtain the result image with reduced striping.

The degree of de-striping can be adjusted in two ways: the size of the sector deleted, and the number of times that the algorithm is run. Deleting too large of an angular sector introduces undesirable new artifacts and decreases the contrast of the image. On the other hand, deleting too small a sector is ineffective. We find it most advantageous to delete an angular sector of 5-10 degrees and to run the processing twice.

Results: We chose a sample of the LAMP data containing numerous swirl features in the South Pole Aitken (SPA) Basin (see Fig. 1a). The region is approximately 1,800 km by 1,300 km and is centered near Mare Ingenii. Note the vertical striping throughout the image. In Fig. 1b, we show the Fourier transform of this image with dashed lines indicating the 7-degree portion of the frequency spectrum to be deleted. We reverse Fourier transform to obtain an image, and for further de-striping we repeat this procedure one more time to obtain the image shown in Fig. 1c. Finally, in Fig 1d, we show the difference image between Fig. 1a and 1c which shows the removal of vertical stripes.

The herein described Fourier transform method can be applied to any image with periodic striping, as long as the striping does not occur with the same frequency as the underlying signal. Fourier transform packages in many modern data analysis platforms make this method among the most straightforward to implement.

References: [1] Gladstone, G. R. et al. (2010) *Space Sci Rev. 150*, 161-181. [2] Cahill, J. T. et al. (2019) *AGU Fall 2019*, Abstract #P43G-3523. [3] Rakwatin, P. et al. (2007) *IEEE Transactions on Geoscience and Remote Sensing 45,* 1844–1856. [4] Schwartz, J. et al. (2019) *Microscopy and Microanalysis, 25*(S2), 174-175. [5] Chen, S. and Pellequer, J. (2011) *BMC Structural Biology* 11:7. [6] Van Buren, D. (1987) *The Astronomical Journal*, *94(4)*, 1092-1094. [7] Zeng, Q. et al. (2020) *Remote Sens. 12(22)*, 3714. [8] Torres J. and Infante S. (2001) *Optical Engineering 40(7)*.

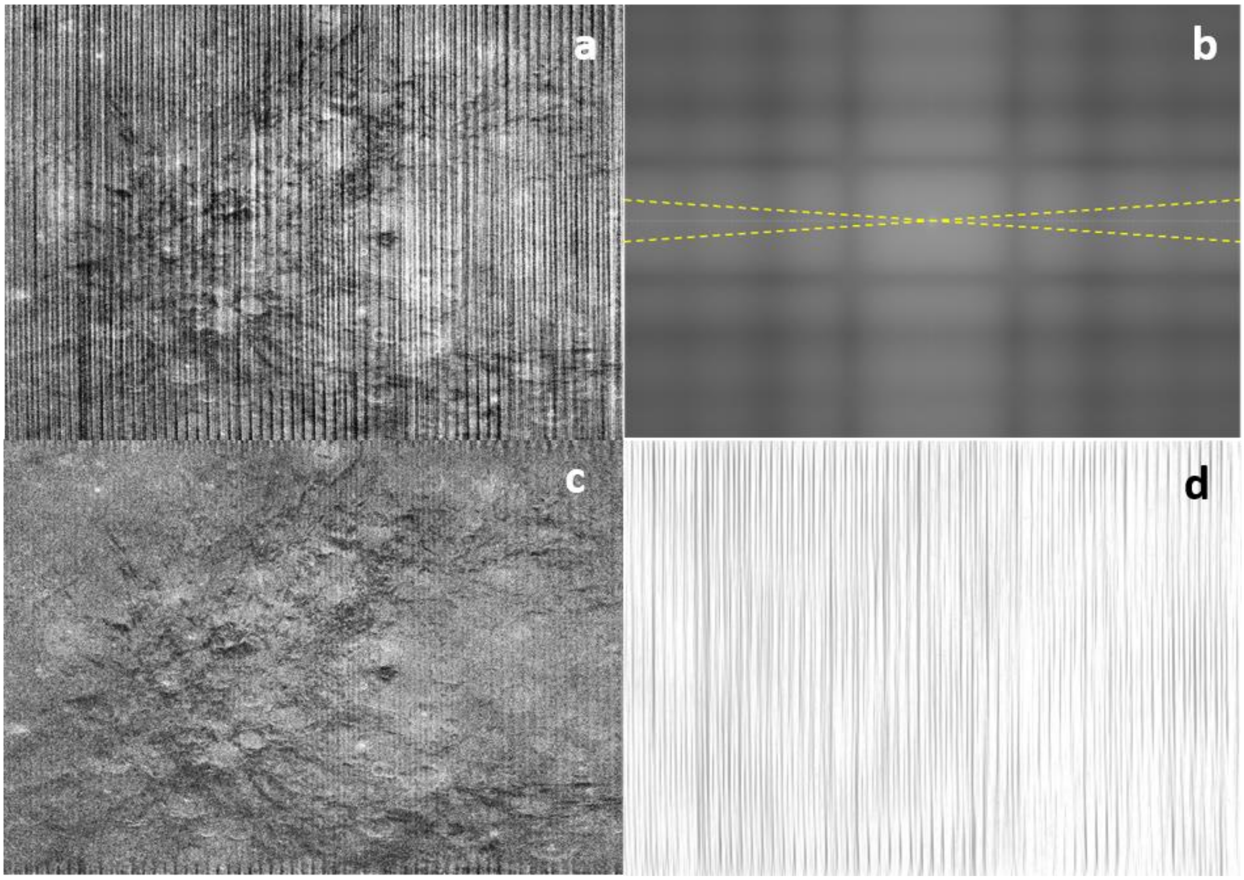

Figure 1. Demonstration of the Fourier de-striping method on a section of SPA lunar swirls. (a) The original data. (b) The Fourier transform of the data with dashed lines indicating the triangular sections of the image to be deleted. (c) The de-striped image. (d) The difference between images (a) and (c).