PRELIMINARY MDIS-WAC SCATTERED LIGHT CORRECTION. S. E. Braden[1], M. S. Robinson[1], S. L. Murchie[2] and F. P. Seelos[2], [1]School of Earth and Space Exploration, Arizona State University, Tempe, AZ [2]Applied Physics Laboratory, Laurel, MD.

Introduction: The Mercury Surface, Space Environment, Geochemistry, and Ranging (MESSENGER) spacecraft launched in August 2004 and its insertion into orbit around Mercury is planned for March of 2011. In-flight images of extended sources in 11-color image sets taken by the Mercury Dual Imaging System (MDIS) Wide Angle Camera (WAC) show a wavelength dependent scattered light component sufficient in magnitude to complicate quantitative spectral and photometric evaluation of MDIS multispectral data [1]. Here we describe a preliminary wavelength-dependent correction for the dominant component of MDIS-WAC scattered light. For background on the MDIS-WAC camera, see [2].

Description of the Problem: The MDIS camera has significant scattered light caused by three known sources: scattering from within the FOV, scattering from just outside the FOV, and a ghosting effect. The dominant source of scattered light originates within the FOV, from diffraction off the CCD and reflection back by surfaces of refractive optics; this appears as a halo surrounding any bright source [1]. Scattered light from outside the FOV originates from diffraction and back-reflection from 14 columns or rows of pixels on the margins of the CCD that are not included in read-out images, and from reflections off components around the CCD.

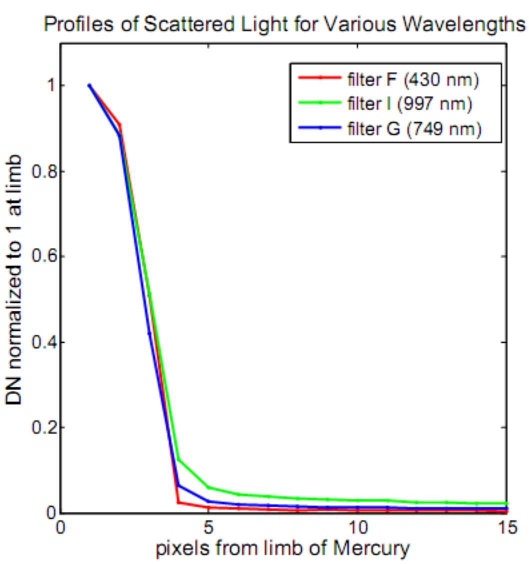

Figure 1. Profiles of Scattered Light for Various Wavelengths. Plot illustrates that scattered light increases for longer wavelengths.

The third source is a ghosting effect with wavelength dependent behavior, in terms of magnitude and location, visible in maximum (~10 second) exposure time images of a bright target (Mercury) against space. The ghost feature is thought to be a reflection of the CCD scatter pattern off the filter wheel. In October 2008, a series of images using Mercury as a small (7 pixels in diameter) extended source was acquired to characterize the scattering pattern in a low ambient light environment that was not attended to during ground calibration. Although successful, the extended nature of the source (not a true point source) in this image series complicates analysis.

This abstract summarizes preliminary efforts to correct scattered light originating from within the FOV. The intensity of scattered light is dependent on wavelength; the greatest amount of scattering is observed at 997 and 1010 nm (3% of the maximum signal at a distance of 10 pixels from the limb of the source: a ~300 pixel diameter Mercury); the least amounts observed at 430 and 480 nm (0.5% of the maximum signal at 10 pixels from the source). Figure 1 shows profiles illustrating the wavelength dependence of the scattered light.

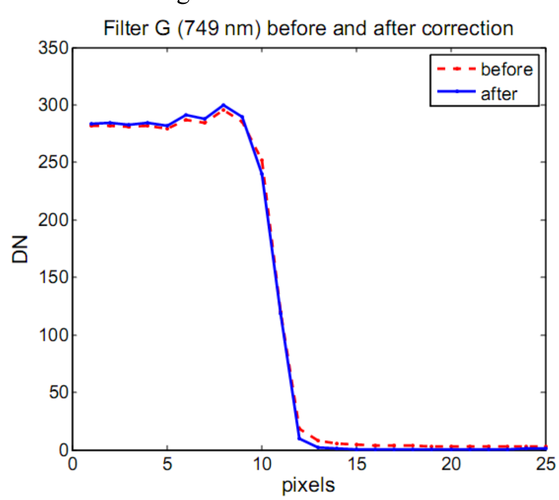

Figure 2. Profiles across the limb of Mercury before and after the deconvolution, for filter G. Conceptually, the deconvolution moves light scattered in space back onto the disk of Mercury.

Description of Correction: We have adapted the optimal correction procedures described by Li et al [3]. As one of the inputs to that algorithm, we developed a point-spread function (PSF) for each filter, describing attenuation of signal from a single pixel as a function of distance. Deriving the PSF began with sampling the scattered light detected by the CCD using whole-disk images of Mercury acquired during the flybys. Using whole-disk images helped avoid complications of scattered light from outside the FOV. We measured the distribution of scattered light detected off the limb of Mercury where ideally scattered light should be zero. Then from the empirical measurements we modeled a simplified, radially symmetric PSF curve with a Moffat softened exponential fit. This approach reduces noise in the PSF which would otherwise cause artifacts in the corrected image. To remove scattered light for a given filter, the PSF is convolved with the Fourier transform of the image at that wavelength, including a noise term to minimize artifacts in the convolution and ringing in the final image [3,4]. To restore the sensor image that would have been present without scattered light, the resulting image is transformed back to the spatial domain. Finally, a conservation of signal coefficient is used to restore the image back to the original DN values.

Results: Table 1 shows example results for one corrected full-disk image of Mercury. Scattered light is reduced by a factor of 4 in the case of some of the longer wavelength filters. Figure 2 illustrates a before and after profile of scattered light off the limb of Mercury. While the correction using the modeled PSF reduces scattered light contributions near the limb of Mercury at 10 px, residual scattered light still remains at distances of 30-50 px. Attempts to remove the residual scattered light component resulted in the introduction of artifacts into the final image, possibly due to the low signal-to-noise ratio of the scattered light far from the limb of Mercury. This correction also does not address the non-radially symmetric nature of the scatter pattern resulting from diffraction off the CCD, which is particularly significant at longer wavelengths (> 829 nm).

Future Work: While the preliminary results of this deconvolution method are promising, the problems of non-symmetric scattering, ghosting, and light scattered from sources outside the CCD's FOV remain. Future work will focus on two areas. First, more robust estimations of the empirical PSF for each wavelength will be derived by incorporating non-symmetrical components of the scatter pattern observed. Second, modeling of scattering from outside the FOV will be attempted using a global mosaic of Mercury reprojected into the plane of sky as viewed from MDIS. In addition, optimization of the noise term in the deconvolution, along with error analysis, must be performed before the final correction can be applied as part of image processing prior to spectral analysis. Refinement of the current preliminary scattered light correction is crucial to quantitative spectral and photometric evaluation of the MDIS multispectral dataset.

References: [1] Hawkins S. E. et al. (2009) *Proceedings of SPIE,* 7441, 74410Z-74410Z-12. [2] Hawkins S. E. et al. (2007) *Space Science Reviews, 131,* 1-4, 247-338. [3] Li H. and Robinson M.S. (2002) *Icarus,* 155, 244-252. [4] Cunningham C. C. and Anthony D. (1993) *Icarus,* 102, 1344–1345.

			Scattered Light Before Correction		Scattered Light After Correction	
Image Name	Filter	Wavelength [nm]	at 5 px	at 10 px	at 5 px	at 10 px
EW0131786026F	6	430	1.0%	0.5%	0.3%	0.1%
EW0131786038C	3	480.4	1.0%	0.5%	0.2%	0.1%
EW0131786034D	4	559.2	1.2%	0.6%	0.3%	0.1%
EW0131786030E	5	628.7	1.4%	0.7%	0.6%	0.1%
EW0131785998A	1	698.8	1.8%	1.0%	0.7%	0.3%
EW0131786022G	7	749	2.0%	1.2%	0.5%	0.2%
EW0131786002L	12	828.6	2.6%	1.5%	0.4%	0.1%
EW0131786010J	10	898.1	4.0%	2.2%	1.3%	0.4%
EW0131786018H	8	948	4.5%	2.6%	1.0%	0.3%
EW0131786014I	9	996.8	4.4%	2.8%	0.7%	0.4%
EW0131786006K	11	1010	4.7%	2.9%	0.8%	0.30%

Table 1. Results of the scattered light correction for one multispectral WAC image. Scattered light is represented as a percentage of total light at the limb of Mercury, at distances of 5 and 10 pixels from the limb. Each measurement of scattered light is from an average of profiles (n = 11) taken across the limb of Mercury.