ANALYSES OF GALILEO SSI DATA FROM EM2: SCATTERED LIGHT EFFECTS; Lisa Gaddis, Alfred McEwen, and Tammy Becker, U.S. Geological Survey, 2255 N. Gemini Drive, Flagstaff, AZ 86001; e-mail: lgaddis@flagmail.wr.usgs.gov

Overview: Scattered light proved to be a small but important component of SSI data from the EM1 encounter of Galileo [1]. In previous analyses, we characterized the effects of the removal of scattered light from the EM1 SSI 6-band multispectral data from Lunmap14 (L14), a whole-disk imaging sequence of the Moon centered near Mare Orientale [2]. An important result of our recalibration effort was an increase in 1-micron band depths of western limb basalts; mare ponds and deposits were shown to have mafic mineral contents comparable to many basalts of the nearside. Here we examine the effects of removal of scattered light from SSI data from EM2 ~whole-disk data from the Lunmos 9 (L9) imaging sequence. We show that scattered light is also an important component for compositional interpretation of the EM2 data, which were acquired after removal of the lens cover, and that its behavior is a complex function of surface albedo.

Introduction: An important element of the calibration of Galileo data is the correction for scattered light, a low-level, wavelength-dependent brightness component [1,2]. Removal of scattered light was shown to be essential for accurate characterization of surface compositions and photometric studies using the Galileo SSI data [2,3]. For the Moon, scattered light strongly influences the 1-micron spectral region and results in inaccurate compositional interpretations of lunar maria near highland boundaries [2]. L9 data have an ~5-km/pixel resolution and are centered near the Apollo 12 landing site, northeast of Mare Humorum. Our objectives are to extend our previous characterization of scattered light to EM2 data, specifically to (1) evaluate the possible effects of the lens cover on SSI scattered light and (2) characterize the effects of scattered light on larger nearside volcanic deposits.

Data from four SSI filters obtained at wavelengths of 410 (VLT), 560 (GRN), 756, and 990 (~1-micron) nm were used in this analysis; data acquired at 660 (RED) and 889 nm wavelengths have yet to be examined. Processing for L9 data has included (1) radiometric calibration, (2) image coregistration to a subpixel level (to within 0.2 pixel; [3]), (3) removal of scattered light, and (4) geometric control and reprojection. For this analysis, we simply compare data before and after correction for scattered light; L9 data have not been photometrically normalized (photometric angles differ by less than 0.5° in the sequence) nor have they been calibrated to Earth-based spectra.

Scattered light is caused by internal scattering from edges, interfaces, etc. within the optical imaging system [e.g., 4]. The intensity of scattered light is wavelength-dependent, with the greatest amounts observed at 990, 889, 756, and VLT wavelengths (3 to 5% of the maximum signal at a distance of 25 pixels from the source, listed in decreasing order), and the least amounts observed at RED and GRN wavelengths (<3% of the maximum signal; [1]). The scattered-light removal algorithm applied here was developed by Ken Klaasen and Ann Harch at JPL; their model predicts scattered light from a source pixel to within a factor of 2 of the scattered light observed in the laboratory for each filter [1]. The correction does not account for "stray light" that may also be captured by the camera from areas outside the field of view; until the possible contribution from stray light is evaluated, the results of this analysis are best shown with ~whole-disk data such as that of L9. Scattered light results in an overall redistribution of light within an image, producing blurring of the image near high-contrast boundaries. Scattered light is expected to be most prominent at the lunar terminator and limb (because contrast is highest in those areas) and at high-contrast albedo boundaries where contamination of the low-albedo spectral response by the scattered light from high-albedo surfaces occurs [1]. Removal of scattered light increases image contrast and thus results in brighter limbs and blacker space and, away from limb regions, darker low-albedo areas and brighter high-albedo areas.

Results and Discussion: Figure 1 shows the results of scattered light removal (shown as % change, or color difference before and after removal) for several sites on the lunar nearside. These
sites include standard calibration areas in Mare Humorum (mh0) and Mare Serenitatis (ms2), the mare pond in Mare Grimaldi (mg), a mare pond in the crater Schickard (ss/m), the pyroclastic deposit at Sinus Aestuum (sa), a highland region south of Grimaldi (h), and a fresh mare crater on the western rim of Mare Humorum (cr). In Figure 1, we observe the least amount of change in the GRN filter data, with increasing amounts for the VLT, 756, and 990 filter data. Also, the bright units (h and cr) increase in brightness and the dark units (mh0, mg, ss/m, and sa) get darker after scattered light removal. These results are consistent with those observed for similar units in the EM1 data, except that the changes at 990 nm for mh0 and mg are roughly two times (-5% and -10%, respectively) the previously observed values of -2% and -5% after scattered light removal. Further, contrary to the expected behavior, the ms2 site shows increasing brightness (-3% at 990 nm) after scattered light removal. These data indicate that scattered light is indeed significant in the EM2 SSI data, regardless of the absence of the lens cover; spectral signatures of mare deposits near highland boundaries appear artificially brighter due to scattered light.

To examine these relations in more detail, we produced images that show color differences (as percent change) before and after scattered light removal. These images generally conform to expectations: the least amount of change is observed for the GRN filter and the most change for the 990 filter; change is highest near the limbs for each filter, with decreasing values as distance from the limb increases; bright units (e.g., southeastern highlands, the crater Copernicus) become brighter and dark units (e.g., maria, pyroclastic deposits) generally become darker. However, "dark" units such as the Mare Serenitatis-2 site become up to 3% brighter (at 990 nm) after scattered light removal. Comparison of the 990-nm-change image with lunar normal albedo data [5] indicate that the amount of scattered light removed is related to the albedo of the surface. Qualitative comparison shows that the cutoff for positive change after scattered light removal is ~0.090 to 0.096: units with normal albedos of ~0.090 or higher (such as that at ms2) become brighter after scattered light removal, and units with normal albedos lower than 0.096 (such as mh0, mg, ss/m, sa, etc.) become darker. Thus, it is not strictly true that "bright gets brighter, dark gets darker" after scattered light removal. These data indicate that scattered light is a complex function of surface albedo. We intend to examine these data further to determine the nature of this relation and the effect of proximity to albedo contrast boundaries.

These studies illustrate the importance of adequate scattered light removal for compositional interpretation of data from Galileo and perhaps other multispectral planetary datasets. The current method of scattered light removal is accurate to within a factor of two [1] and does not account for (1) the possibility of stray light from outside the image FOV or (2) possible asymmetric behavior of scattered light. Refinement of the technique for scattered light removal is currently in progress [K. Klaasen, B. Little, and C. Anger, pers. comm., 1995].