RECALIBRATION OF GALILEO SSI LUNAR DATA FROM EM1: THE EFFECTS OF SCATTERED LIGHT REMOVAL; Lisa Gaddis, Alfred McEwen, and Tammy Becker, U.S. Geological Survey, 2255 N. Gemini Drive, Flagstaff, AZ 86001

Overview: The radiometric calibration and systematic processing procedures for Galileo Solid State Imaging (SSI) multispectral data from the first Earth-Moon encounter (1990; [1]) have been updated. We applied these procedures to Lunmap14 (L14), a whole-disk imaging sequence of the Moon centered near Mare Orientale. L14 data, which were obtained at a 20° phase angle, have a spatial resolution of ~8 km/pixel, and a subspacecraft position of -20.7° latitude and 98.3° longitude. Data from six SSI filters were used in this analysis, and they were obtained at nominal wavelengths of 410 (VLT), 560 (GRN), 660 (RED), 756, 889, and 990 (~1-micron) nm. A major element of this recalibration is the correction for scattered light, a low-level, wavelength-dependent brightness component [2]. The present correction for scattered light does not account for "stray light" that is also captured by the camera from areas outside the field of view, so the results of this analysis are best shown with whole-disk data such as that of L14. After removal of scattered light, the 1-micron band depths of limb basalts show the greatest change: they are ~3% deeper than those of the previously calibrated data. These results resolve the need for the anomalously low-Fe lithologies of limb basalts as suggested by the shallow 1-micron band depths in the original analyses [3, 4]. Small mare ponds and limb basalts are now shown to have mafic mineral contents comparable to many basalts of the nearside.

Data Processing: Systematic processing for L14 data has included: (1) radiometric calibration (corrections for dark current, shutter offset, vignetting, and removal of dust-rings and reflections from the lens cover), (2) image coregistration to a subpixel level (to within 0.2 pixel; [5]), (3) removal of scattered light, (4) geometric control and reprojection, (4) photometric-function normalization, and (6) calibration to Earth-based data. The subpixel coregistration and scattered-light removal procedures represent significant improvements over the initial processing of the Galileo SSI data [5]. As in the previous calibration process, L14 data were first calibrated to the secondary standard mare area in Mare Humorum (MH0) because it was in the field of view of the images. The relatively calibrated data (SSI/MH0) were then related to the primary standard areas in central Mare Serenitatis (SSI/MS2) and in the highlands at the Apollo 16 site (SSI/Sun).

Scattered light is an artifact of the imaging process--it is a low-intensity brightness component caused by internal scattering from edges, interfaces, etc. within the optical imaging system [6]. Scattered light is here distinguished from "stray light" that is also captured by the camera from areas outside the field of view. In a whole-disk view (such as L14), scattered light is expected to be the sole contributor to the additive light component. For a partial-disk view (such as most of the data from SSI and Clementine), both scattered light and stray light contribute to the additive brightness. The primary effect of these additive light components is to blur the imaged data; removal of these components results in enhanced image contrast (dark units are darker, bright units are brighter). At present, removal of scattered light alone from a partial-disk image leaves a residual brightness component that is attributed to stray light. No adequate method for the removal of stray light currently exists. This is an important problem that must be resolved for effective calibration of much of the data from Galileo SSI and NIMS, Clementine, NEAR, and other missions with multispectral imaging experiments. As described below, the effects of scattered light can make accurate compositional interpretation of spectral data difficult, if not impossible.

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; [2]). The scattered-light removal algorithm applied in this study was developed by Ann Harch at JPL. Harch's algorithm employs a unique scattering function for each filter; each function describes the attenuation of illumination on a single pixel as a function of distance from that pixel [2]. Table 1 shows the results of scattered light removal (shown as % change, or color difference before and after removal, with + = brightening, and - = darkening) for a highland area NE of Orientale and for the mare pond in Mare Grimaldi, as compared to the standard mare calibration area in Mare Humorum (MH0).

Results and Discussion: The spectral effects of scattered light removal indicate that for small mare ponds in particular the 1-micron band depth (as measured by the 756/990 band ratio) will be ~3% deeper after scattered light removal. Spectral signatures of small mare deposits located within the lunar highlands of the western limb are artificially "bright" due to scattered light at 990 nm. Further, the UV/VIS ratio (as measured by the VLT/GRN band ratio) should show changes of 1% or less following scattered light removal. Recall that the 1-micron band depth is commonly related to the mafic mineral content (e.g., pyroxenes, olivine) of mare basalts, and the UV/VIS ratio has been empirically related to the titanium content of mature mare soils [e.g., 4, 7]. In the newly calibrated EM1 data, deeper 1-micron band depths indicate that limb basalts have more iron-rich minerals than was apparent in the analyses of data from the previous calibration [3,4]. Estimates of titanium content of limb basalts, interpreted as intermediate in composition in earlier analyses [3,4], should remain relatively unchanged.

Lunar spectra for limb basalts of the Mare Orientale region illustrate the effects of the removal of scattered light on compositional interpretation (Figure 1). Figure 1(a) shows spectra from two mare pond sites each in Mare Orientale and Mare Grimaldi (after [4]) derived from the previous calibration of EM1 data, and Figure 1(b) shows the same spectra after removal of scattered light from the L14 data. The observed weak or nonexistent 1-micron absorptions of spectra from the initial calibrations were interpreted to indicate a very low mafic mineral content for these mare deposits [3,4]--such a low abundance of mafic minerals is unusual for nearside basalts, and it suggested an inherently different lithology for these limb basalts. Note that although only the 410-nm reflectance data for 15MOR are unchanged after recalibration, all of the the UV/VIS ratios are still medium to medium-high, indicating that these mare deposits have intermediate titanium contents [3,4]. Also, the 1-micron band depths in the recalibrated data are appreciably lower than in the original data, indicating that the mafic mineral contents of these limb basalts are higher than previously thought. Although the 1-micron band depths in the recalibrated data would not be classified as "strong" [7], they are in fact comparable to those of many other nearside basalts (e.g., the 15MOR spectrum is similar to that of the Flamsteed ring basalt at the Surveyor site in southern Mare Procellarum). These studies serve to illustrate the importance of adequate scattered light removal for compositional interpretation of data from Galileo, Clementine, NEAR, and other multispectral planetary encounters.

References: [1] Belton et al., 1992, *Science, 255*, 570; [2] Klaasen, 1993, Galileo SSI Subsys. Cal. Rpt. Pt. 2, JPL 625-210; [3] Greeley et al., 1993, *JGR, 98,* 17183; [4] Pieters et al., 1993, *JGR, 98,* 17,127; [5] McEwen et al., 1993, *JGR, 98,* 17,207; [6] Slater, 1980, *Rem. Sens., Optics and Opt. Sys.*, Addison-Wesley; [7] Pieters, 1978, *PLPSC 9th*, 2825.

Table 1. Scattered Light Removal

Site	% Change	Filter(s)
Highlands	+3%	990, 889, 756
	+2%	RED, VLT
	+1%	GRN
Mare pond	-5%	990
	-1%	756, GRN
	<-1%	889, RED, VLT
MH0	-2%	990
	-1%	GRN
	<-0.5%	756, 889, RED, VLT

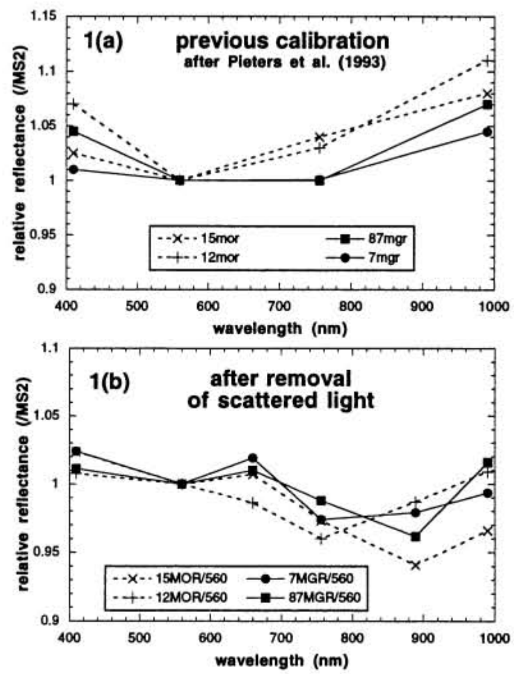

Figure 1. L14 mare ponds >>>