Spectrogoniometric Measurements and Models of Mars Analog Soils. J.R. Johnson[1], M.K. Shepard[2], W. Grundy[3], R.V. Morris[4], T.S. White[5], [1]U.S. Geological Survey, 2255 N. Gemini Dr., Flagstaff, AZ 86001, jrjohnson@usgs.gov, [2]Bloomsburg University, Bloomsburg, PA, [3]Lowell Observatory, Flagstaff, AZ, [4]Johnson Space Center, Houston, TX, [5]Penn State University, University Park, PA.

Introduction: Laboratory visible/near-infrared multispectral goniometer observations of ten Mars analog soils have been acquired using the Bloomsburg University Goniometer (BUG) [1-4]. Sufficient data were acquired at a variety of incidence, emission, and phase angles to allow modeling using Hapke radiative transfer theory. This provides additional constraints on interpretations of similar observations of the martian surface that continue to be acquired by orbital and landed cameras and spectrometers [5-9].

Observations. Multispectral measurements of the samples were acquired at incidence angles of 0-60°, emission angles of 0-80°, and phase angles of 3-140° using the BUG facility, comprising 680 measurements per wavelength. Acquisition and calibration procedures are outlined in [1] and are somewhat similar to techniques used by [10]. Samples were poured into cups and the surface was carefully smoothed, followed by gentle tapping to settle the contents evenly. Five samples were observed in eleven narrowband filters ranging from 430 nm to 990 nm: JSC-1 (bulk) and four samples from Mauna Kea (HWMK101, HWMK904, HWMK940, and HWMK600) all sieved to < 1 mm grain size [11]. Four samples were acquired in four filters (450, 550, 750, and 950 nm): HWMK600 (150-1000 μm), JSC-1 (< 45 μm; [12]), Pahala Ash (< 53 μm) [13], and a mid-Cretaceous spherulitic paleosol sample SCB5 (Sioux City, Iowa) containing a fine-grained silt/sandstone matrix in which siderite/hematite spherules <3 mm in diameter were embedded. This terrestrial paleosol is analogous to martian spherules observed by the MER Opportunity rover. We extracted and cleaned spherules from the paleosol to perform the following experiment: After acquiring data of the powdered matrix material (<45 μm), we then gently sprinkled the extracted spherules on top of the matrix-only sample (Figure 1) to examine the photometric effects of small spherules on a fine-grained substrate.

Analyses. Hapke models were run using Henyey-Greenstein (HG) phase functions to determine the asymmetry parameter (ξ) for a 1-term HG, and the *b* (asymmetry parameter) and *c* (backscattering fraction) parameters for a 2-term HG [6]. All models included the single scattering albedo (*w*) and macroscopic roughness parameter ($\bar{\theta}$), as well as the opposition effect magnitude (*B0*) and width (*h*). A reduced chi-square (χ_ν^2) estimate of goodness of fit was also derived. The error on each fitted parameter was estimated by testing how χ_ν^2 changed when a particular parameter was purposely varied from its original best-fit value [6].

Results. Two-term HG models tended to give the best model fits (as determined by the χ_ν^2 value), although at the expense of some variables being under-constrained by the data (e.g., *B0*). The 2-term HG phase functions for most samples were similar to the experimental results from [15] for rough spheres with a moderate density of internal scatterers (Figure 2). Samples with fewer fine-grained components were more broadly backscattering (low *b*, high *c* values). The SCB5 matrix and JSC1 (< 45 μm) samples were more narrowly forward scattering in both 1-term and 2-term HG models, consistent with the smoother surface of these fine-grained samples. The *h* values from 1-term HG models were largest for the finest-grained samples, consistent with the more uniform grain size and lower porosity of these samples. However, the *h* values from the 2-term HG models were somewhat less well constrained, particularly for the SCB5 sample with the added spherules.

Comparison of the SCB5 samples with and without the added spherules was particularly interesting. Upon addition of the spherules, the single scattering albedo decreased substantially (Figure 3), and the average macroscopic roughness parameter increased from 7° to 26°. The average 1-term HG asymmetry parameter (ξ) changed from very forward scattering (+0.094) to very backscattering (-0.178). Similarly, the 2-term HG function parameters became more backscattering (Figure 2). (It is unclear why the 950 nm model results for the “SCB5 with spherules” are an outlier in Figure 2, with *c*~0, *b*~0.8). The 1-term HG *h* value also decreased from 0.088 to 0.030 with the addition of spherules, consistent with the less uniform grain size and/or greater porosity of the spherule-rich sample. (The 2-term *h* values were under-constrained by the data). Spectrophotometric modeling of Pancam data of spherule-rich soils at the MER rover Opportunity landing site in Meridiani Planum showed similar 2-term HG phase function parameters for the soils near the crater Vostok south of Endurance crater [7], as overlain on Figure 2.

Future work with the BUG facility will investigate lunar analog soils in preparation for upcoming lunar missions [cf. 16-17].

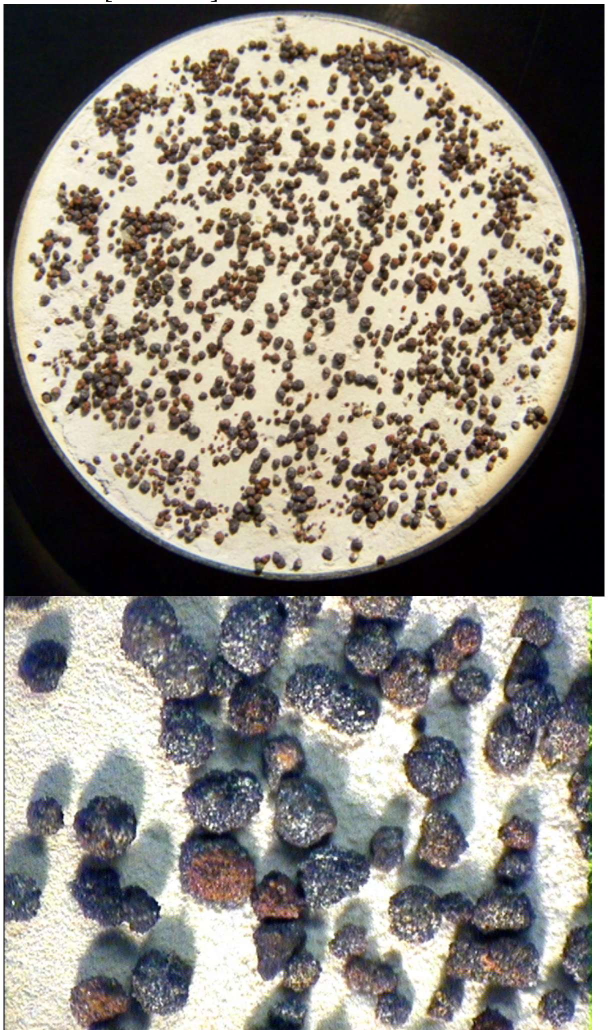

Figure 1. (*top*) Photograph of SCB5 matrix soil coated with extracted spherules [14]; field of view is 6 cm across; (*bottom*) photographic close-up of same sample; field of view is ~ 10 mm.

References: [1] Shepard, M.K., in *Solar System Remote Sensing Symposium*, abstract #4004, LPI, 2002; [2] Johnson, J.R., et al., *JGR*, 111, E12S07, doi:10.1029/2005JE002658, 2006; [3] Johnson, J.R., W.M. Grundy, and M.K. Shepard, *Icarus*, 171, 546-556, 2004; [4] Shepard, M.K., and P. Helfenstein, A test of the Hapke photometric model, in press, *JGR*, 2007. [5]Johnson, J.R., et al., Physical properties of the martian surface from spectrophotometric observations, Ch. 19, *in The Martian Surface: Composition, Mineralogy, and Physical Properties*, in press, Cambridge University Press, 2007; [6] Johnson, J.R., et al., *JGR*, 111, E02S14, doi:10.1029/2005JE002494, 2006; [7] Johnson, J.R., et al., *JGR* 111, E12S16, doi:10.1029/2006JE002762, 2006; [8] Pinet, P.C., et al., LPSC *XXXVI*, # 1694, 2005; [9] Pinet, P.C., et al., LPSC 37th, # 1220, 2006.; [10] Gunderson, K., et al., Plan. Space Sci., 54, 1046-1056, 2006; [11] Morris, R.V., et al., *JGR*, 105, 1757, 2000; Morris, R.V., et al., *JGR*, 106, 5057, 2001; [12] Allen, C.C., et al., LPSC *XXIX*, #1690, 1998; [13] Johnson, J.R. et al., *JGR*., 107(E6), 10.1029/2000JE001405, 2002; [14] Ludvigson, G.A., et al., Geology, 26,1039-1042. 1998; [15] McGuire, A.F., and B.W. Hapke, *Icarus*, 113, 134-155, 1995; [16] Domingue, D., and F. Vilas, LPSC XXXVI #1978, 2005; [17] Gunderson, K., et al.,LPSC XXXVI, #1781, 2005.

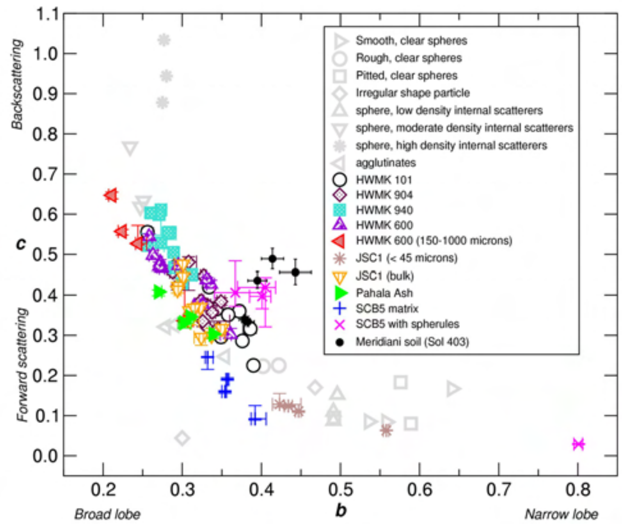

Figure 2. Two-term Henyey-Greenstein (HG) phase function parameters for all soils shown with values for synthetic particles from laboratory work by [15]. Asymmetry parameter *b* (narrow scattering lobes = large values) and backscattering parameter *c* (backscattering materials = large values) [cf. 6-7]). Also shown are values for spherule-rich soils near Vostok crater from MER Opportunity Pancam data [7], which are similar to the SCB5 soils with spherules.

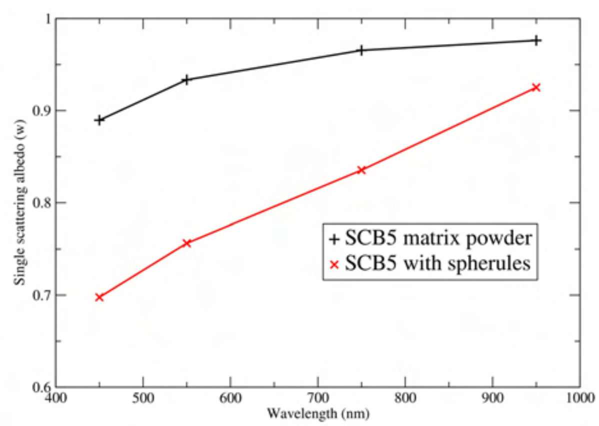

Figure 3. Single scattering albedo values from 2-term HG models for SCB5 powder with and without spherules (Figure 1).