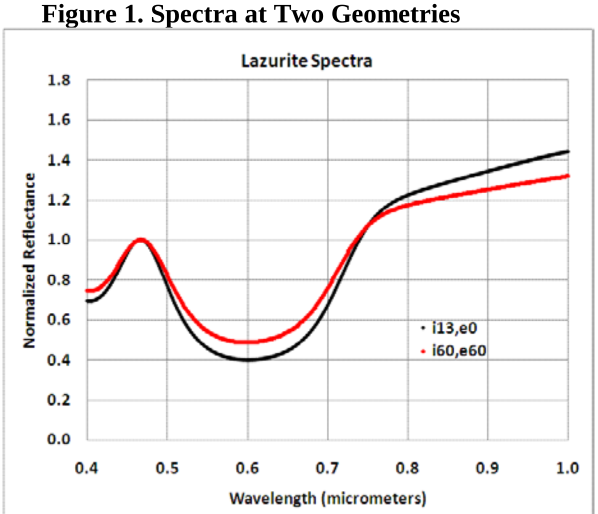
LABORATORY MEASUREMENTS OF BAND DEPTH VARIATION WITH OBSERVATION GEOMETRY. M. K. Shepard[1] and E. Cloutis[2], [1]Bloomsburg University, Department of Geography and Geosciences, 400 E. Second St., Bloomsburg, PA 17815, mshepard@bloomu.edu, [2]Department of Geography, University of Winnipeg, Winnipeg, Manitoba, Canada, e.cloutis@uwinnipeg.ca.

Introduction: A significant issue for spacecraft observing planetary surface reflectance spectra is that mineral absorption bands are functions of observation geometry. Mission constraints often require observations to be taken at a wide range of lighting and viewing geometries, making it difficult to determine whether differences in absorption band depths are due to mineralogical variations, particle size differences, or observation geometry[1].

To study this problem, we compared measurements of particulate lazurite, a sample with a deep absorption feature at 0.6 µm (Fig 1), at two facilities. We measured the full bidirectional reflectance distribution function (BRDF) at three wavelengths using the Bloomsburg University Goniometer (BUG), and measured high resolution spectra at select geometries using an ASD Field Spec Pro HR spectrometer at the University of Winnipeg.

Our goal was to characterize how the band depth varied over the entire BRDF using BUG, and compare predictions from these data to observations acquired with high spectral resolution at a few select lighting and viewing geometries.

Figure 1. Spectra at Two Geometries



Measurements: We measured the full BRDF of a particulate sample of lazurite with the Bloomsburg University Goniometer with filters centered at three wavelengths: 0.480 µm (FWHM 0.010 µm), 0.601 µm (FWHM 0.027µm), and 0.838 µm (FWHM 0.080 µm). The wavelengths were chosen to measure the depth of an absorption at 0.6 µm.

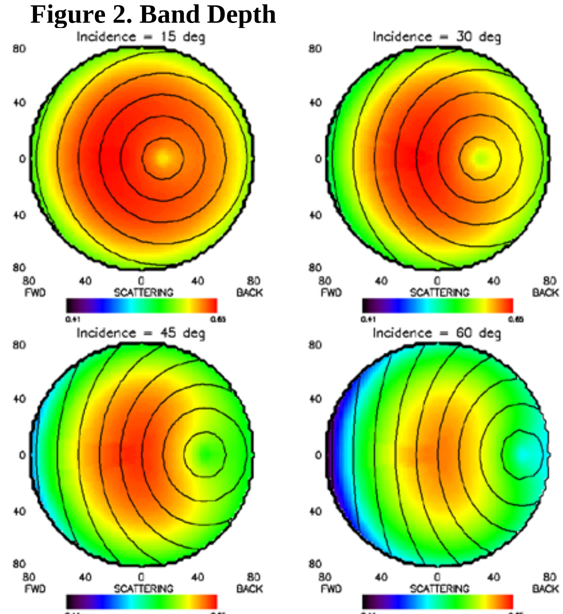
Using these data, we calculated the band depth using the following formula:

$$\text{Depth} = 1 - (Rb / Rc)$$

[1] where Rb is the reflectance at the band center (0.6 µm in this case) and Rc is the reflectance of the continuum at the band center. Because the BUG data are of limited spectral resolution, we do not remove the continuum (detrend) prior to calculating band depth [1]; instead, we assume the continuum to be the line connecting the reflectances at 0. 48 µm and 0.84 µm and the minimum to be at 0.60 µm.

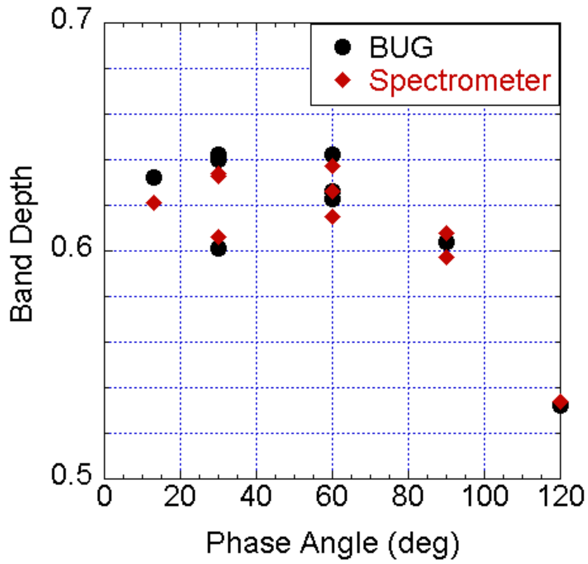
We generated plots of band depth as a function of incidence angle (Fig. 2). Each plot in Figure 2 illustrates the band depth for all observations at a given incidence angle. The emission angle is the radial distance from the center of each plot (0° at center, 80° at edges), and the azimuth is 0° to the right and 180° at the left. The contours are phase angle in 15° intervals and opposition is in the center of the "bulls-eye." The colors indicated the depth of band with the scale below; reds are the deepest band depths (max 0.65), blue to black are the most shallow (min 0.41).

Figure 2. Band Depth



For comparison, we made high spectral resolution measurements with the Winnipeg spectrometer at ten different geometries with phase angles ranging from 13° to 120° (Fig. 1). We calculated band depth using the same method as with BUG and find them consistent. A comparison of both band depth measurements in shown in Figure 3.

Figure 3. BUG vs. Spectrometer

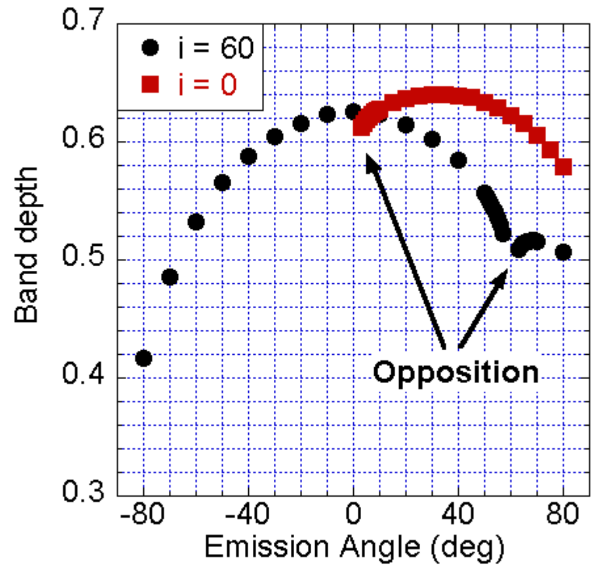


Results: We find that band depth varies by 50% over the observed range of geometries (g = 3°-140°) and likely more if phase angles exceed 140°. The shallowest band depths occur at the highest phase angles. For any given phase angle, those with the larger incidence or emission angles tend to have shallower band depth.

Maximum band depths are observed at intermediate phase angles; in our data set, we find little variation (Δ=0.025 or about a 3% change) in depth for phase angles of 20°-70° (mean ~45°) when incidence and emission angles are restricted to *i,e* < 50°. We find a significant drop in band depth as opposition is approached, especially at higher incidence angles. Two examples are illustrated in Figure 4.

Using the raw high-resolution spectra, we find the band minimum to be at 0.599 µm at both low phase (g=13°) and high phase (g=120°) geometries. However, if we detrend the data first, we find the band minimum to shift as a function of observation geometry: for low phase (g=13°) the minimum is at 0.628 µm, while at high phase angle (g=120°), the minimum is at 0.619 µm. This shift is caused by the greater red-slope in the low phase angle data; the low-phase curve in Fig. 1 must be 'tipped down' more to detrend than the high-phase curve, moving the minimum further to the right.

Figure 4. Band depth at two incidence angles



Applications: Based on these preliminary results, spectra taken between phase angles of 20°-70° where neither incidence or emission exceeds 50° should be comparable and relative band depth variations should not exceed 5% . Variations larger than these, under these observation constraints, are likely caused by grain size or compositional changes.

Band depth variations become increasingly pronounced at high incidence, emission, and phase angles. Band centers are also affected as greater amounts of reddening are removed during detrending. Direct comparison of spectra that exceed the constraints listed above is hazardous.

References: [1] Clark E. F. and Roush, T. (1984) *JGR, 89*, 6329-6340.

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