WHAT IS THE SURFACE COMPOSITION OF CERES?. A. S. Rivkin[1] and E. L. Volquardsen[2], [1]JHU Applied Physics Laboratory 11100 Johns Hopkins Rd. Laurel MD 20723, andy.rivkin@jhuapl.edu [2]Institute for Astronomy, University of Hawaii, 640 Aohaku Place, Hilo, HI 96720.

Background: Ceres has been the subject of increased attention of late, with our knowledge of this body increasing rapidly. Shape models based on HST observations have led to the contention that Ceres must be differentiated, and may have a subsurface ocean [1-4]. Consensus as to the surface composition of Ceres remains elusive, however. Work in the 1970s and 1980s concluded that Ceres was related to carbonaceous chondrites [5], though this work was based on low-resolution spectra.

An absorption near 3 μm, diagnostic of some kind of hydrated species, has been observed on Ceres for nearly 30 years [6-8], but there is no agreement about the most likely species. Ceres' 3-μm band shape is unlike that of most C-class asteroids, and is not known in the meteorites. The first observations were interpreted as indicative of water ice frost [9], which is only marginally stable on Ceres. Later work suggested ammoniated clays as a better fit [10], though such minerals were have never been seen in meteorites. More recent observations have been interpreted as matching irradiated organic materials in the presence of ice [11]. The majority of hydrated C-class asteroids are consistent with CM meteorites, but because some other asteroids have been found with band shapes like Ceres [8], knowing what is responsible has implications beyond Ceres alone.

Observations: In order to address thes questions, we have obtained spectroscopy of Ceres in the 0.8-4 μm region in May 2005 using SpeX on the IRTF in long-wavelength dispersed (LXD) and prism modes. The prism mode data were reduced using a series of IRAF packages and IDL routines, fitting an atmospheric model to the data to remove any residual telluric effects, as done in [12]. The LXD data used Spextool [13], followed by further processing using IDL, in the same manner as the prism-mode reductions. The LXD-mode data further underwent modeling to remove the influence of thermal flux. Observations were performed over all of Ceres' rotation period, allowing large-scale differences to be addressed if present. The data presented here are whole-night averages.

Results: Figure 1 shows a composite spectrum of Ceres from 0.4-4.0 μm. The visible region is from the Small Main-Belt Asteroid Survey (SMASS)[14], while the other regions are the new SpeX data. There are several spectral features in this wavelength region: a wide band centered near 1.25 μm, a dropoff shortward of 0.5 μm, and the aforementioned 3-μm absorption band (or set of bands). The gap in data from ~2.55-2.85 μm is where interference from the Earth's atmosphere does not allow observations.

Also shown is MAC 87300, an ungrouped carbonaceous chondrite[15]. Its spectrum has a very similar shape near 1.25 μm, probably due to serpentines being present in both object. However, its 3- μm band shape is markedly different from Ceres'. The broad 3- μm band on Ceres has at least two sub-bands, centered near 3.05 and 3.30 μm. The 3.05 band has been attributed to a water ice frost, ammoniated phyllosilicates, and irradiated organic material, as mentioned before [9-11]. We also suggest that Fe-rich phyllosilicates can have band minima near 3.05 μm [16], and may provide a relatively straightforward way of explaining that absorption band. The 3.30 μm band could possibly be due to aromatic hydrocarbons, but is also found in ammoniated clays, which supports [10]. A determination of whether the 3.30 and 3.05 μm bands covary or not is underway, and should help address whether one or more than one species are responsible for these two bands.

We have also found evidence for additional absorption features on Ceres near 3.8 μm, shown in Figure 2. These features are most consistent with carbonates, which are found in meteorites. If confirmed, carbonates could also be responsible for the 3.30 μm band. We will present these data and discussion of implications for Ceres.

References: [1] Li et al. (2005) *LPSC XXXVI* #1345. [2] McCord and Sotin (2005) *JGR 110* 10.1029/2004JE002244. [3] Erard et al. (2005) *LPSC XXXVI* #1388. [4] Thomas et al. (2005) *Nature 437*, 224-226. [5] Larson et al. (1983) *Icarus 56* 398-408. [6] Lebofsky (1978) *MNRAS 182* 17-21, [7] Jones et al. (1990) *Icarus 88* 172-192. [8] Rivkin et al. (2003) *MAPS 38* 1383-1398. [9] Lebofsky et al. (1981) *Icarus 48* 453-459. [10] King et al. (1992) *Science 255* 1551-1553. [11] Vernazza et al. (2005) *AA 436* 1113-1121.. [12] Sunshine et al. (2004) *MAPS 39* 1343-1357. [13] Cushing et al. (2003) *PASP 115* 383-388. [14] Bus and Binzel (2002) *Icarus 158* 106-145. [15] Hiroi et al. (1997) *LPSC XXVIII* 577-578 [16] Calvin and King (1997) *MAPS 32* 693-701.

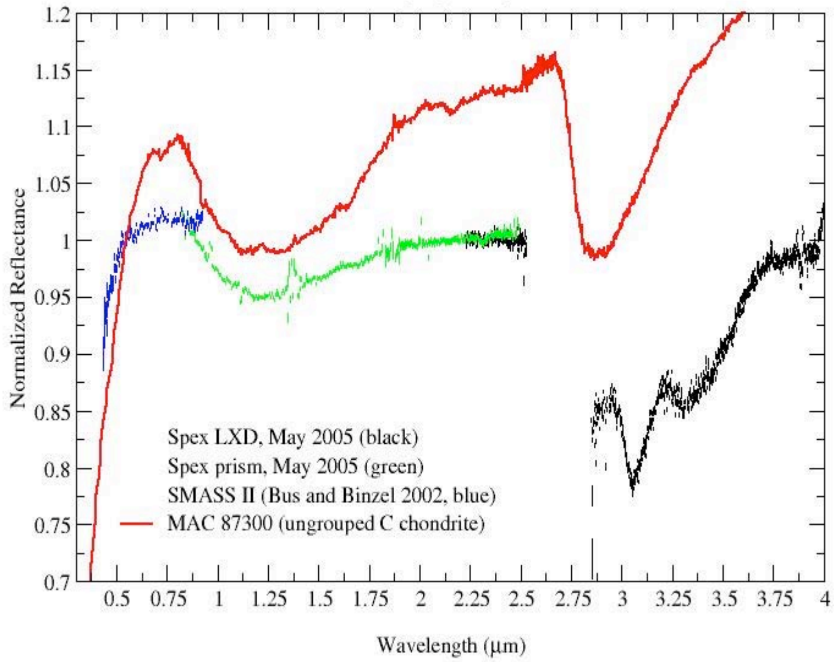

Figure 1: Ceres spectrum from 0.4-4 μm. Notable are the absorption bands near 1.25 μm (also seen in MAC 87300, from [11]) and the broad 3-μm band with minima near 3.05 and 3.30 μm. The MAC 87300 spectrum also has a 3-μm band, but like other known meteorites, it does not match Ceres in that spectral region.

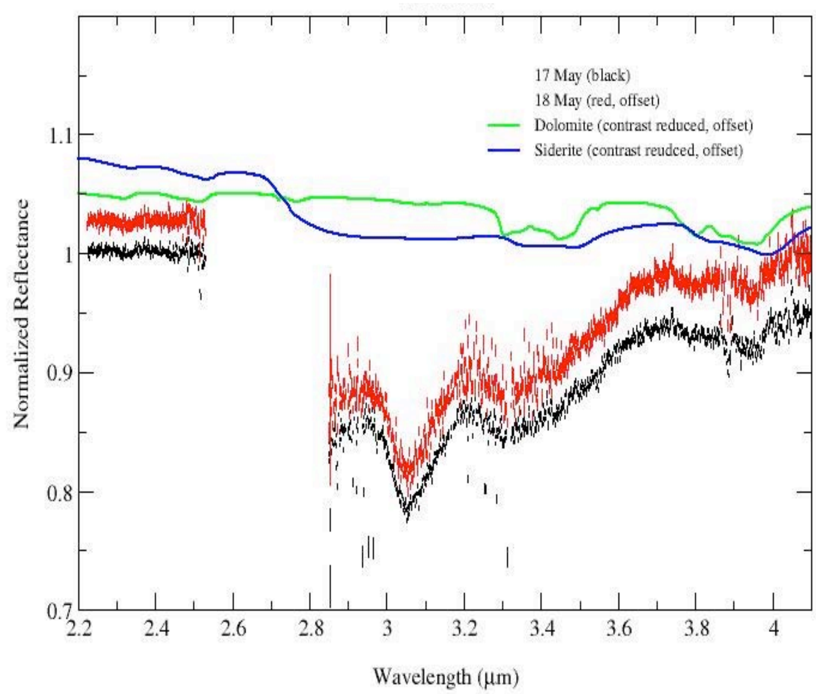

Figure 2: Dolomite and siderite are both carbonates seen in carbonaceous chondrite meteorites (spectra from ASTER and RELAB). Features near 3.8 μm in Ceres' spectrum are reminiscent of those found in carbonates. While the observations are more uncertain near 3.3-3.4 μm they could also plausibly be due to carbonates. While dolomite and siderite are shown, calcite also has similar spectral features in this wavelength region. All of the spectra are normalized to 2.5 μm, and offset from one another for clarity.