UV ABSROPTION FEATURES OF ASTEROID 1 CERES. Jian-Yang Li[1], L. A. McFadden[1], M. F. A'Hearn[1], L. M. Feaga[1], C. T. Russell[2], A. Coradini[3], C. De Sanctis[3], E. Ammannito[3]. [1]University of Maryland at College Park, MD, USA (jyli@astro.umd.edu); [2]Univeristy of California and Los Angeles, CA, USA; [3]CNR, Instituto di Radioastronomia, Roma, Italy.

Introduction: Asteroid (1) Ceres is a unique asteroid, or dwarf planet, yet to be well understood. Classified as G-type [1], Ceres has been generally considered to consist of carbonaceous chondrite material [2]. The weak but complex spectral features in the 3-µm region of the spectrum of Ceres has been known for a long time, but no agreement has been reached on the identification of the specific species. Early studies suggested hydrated and/or ammoniated minerals accounted for the feature [3,4,5]. Recently the discovery of carbonates and iron-rich clays was reported from the 3µm region [6]. A 3-σ detection of water emission off the limb of the north pole of Ceres was reported [7], but never has been repeated. The most recent measurement of the size and shape of Ceres suggested ~25% water in its composition, and a differentiated interior [8]. The evolutionary models suggested liquid water in a mantle beneath the surface in the past, and even possibly today [9]. As one of the two target asteroids of NASA's Dawn mission, scheduled to be orbited in 2015 [10], significant effort has been made to study the composition of Ceres in various spectral regimes.

The ultraviolet (UV) spectral region is substantially underexploited in the study of asteroids. Recent imaging photometry of Ceres using Hubble Space Telescope (HST) has drawn our attention to the UV region for Ceres. [11] reported a possible wide and strong UV absorption feature in Ceres' spectrum. In order to confirm the existence of the absorption band and to characterize it, we obtained new images as well as slitless spectra of Ceres from 120 to 200 nm, using the Solar Blind Channel (SBC) of the Advanced Camera for Surveys (ACS) onboard HST. We will report the preliminary results of photometric measurements from the far-UV images and discuss the implications.

Observations and Data Reduction: Three HST orbits were used to observe Ceres in the far-UV. During each orbit, one 600-sec image of Ceres was obtained through the F125LP filter. The remaining time was used to integrate three slitless spectra of Ceres through the objective prism PR130L, reaching a total exposure time of ~1800 sec. All data were first processed by the data reduction pipeline at the Space Telescope Science Institute. We then measured the total brightness of Ceres in DNs from all exposures, including both images and spectra. Visual inspections show that, within the 200-pixel radius aperture (Ceres being resolved to ~25 pixels in diameter), there should only be a tiny fraction of flux left out of the total flux measured from spectra. The total measured DNs were converted to fluxes using the photometric calibration keyword, PHOTFLAM. In order to calculate the reflectance of Ceres in I/F, where I is the reflected intensity, and πF is the incident solar flux, we took a high-resolution solar spectrum, modulated it for the system throughput with the corresponding filter and prism and calculated the anticipated solar flux at Ceres.

The data reduction of the slitless spectrum of Ceres is still ongoing. This process is substantially complicated by the large angular size of Ceres and the slitless nature of the spectrum. Specifically, the observed spectrum of Ceres is a convolution of the real spectrum and the width of Ceres' disk, and therefore the spectral resolution is degraded. We will exercise deconvolution techniques to restore the spectral resolution.

UV Spectrum of Ceres: The UV spectrum of Ceres is shown in Fig. 1, combining the new SBC data with previous photometric measurements of Ceres from HRC [11] and HST Faint Object Camera (FOC) [12], as well as with the 24-color survey at visible wavelengths [13]. Overall, the reflectance spectrum of Ceres is featureless and almost flat at visible wavelengths, and starts to decrease sharply at a relatively short wavelength, around 400 nm, unlike many of the spectrally similar C-type asteroids, where the UV drop-off starts around 600-700 nm. An absorption band, which is centered at ~280 nm, is ~150 nm wide, and has ~30% reflectance at the band center relative to that outside of the band, is seen. The visible albedo of Ceres is ~8%, and ~3% at the center of the absorption. However, the albedo of Ceres at 150 nm is ~15% as measured from SBC data.

All previous data points, except for the one at ~160 nm from the FOC reported by [12], have 5-10% or less uncertainties. The large error bar (~45%) of the 160 nm data point actually represents the rotational variations of Ceres. The real measurement error was about 10% (Fig. 4 in [12]). While in our measurement, the photometric range at 145 nm is only about 0.08 mag, or 8%. This photometric range is about twice as much as that observed at visible wavelengths, and is consistent with the trend of increasing albedo contrast on the surface of Ceres from V-band to UV [11], but is much less than that measured from FOC at 160 nm.

The measurement uncertainties of the albedo of Ceres at 145 nm due to noise are less than 10%. No

UV bright objects are visible in any of the images or spectra used to measure the total brightness of Ceres. Considering the absolute calibration, correction for geometric distortion, point spread function, red leak, etc., the total uncertainty of the measurement is estimated to be ~<20%.

The reflectance of Ceres in the far-UV is unusually high compared to its reflectance at longer wavelengths. However, it appears to be consistent with the trend of reflectance change from 280 to 160 nm, despite the high uncertainty of the data point at 160 nm. Even if the uncertainty of the albedo measurement at 145 nm wavelength is much higher than our estimate, and the actual reflectance is only about a half of the measured value, or even close to the lower limit of the FOC data point at 160 nm, the UV absorption band centered at 280 nm appears to be confirmed.

Discussions: UV absorption features at 200-300 nm have been discovered on other planetary bodies, but are all different from that that was observed on Ceres. For example, an S-O band is believed to be responsible for the UV absorption on Europa [14], and the Hartley band of ozone is considered to be the cause of UV absorption on Ganymede [15]. H_2O_2 [16] and TiO_2 [17] can also generate absorption bands at this wavelength. However, none of them matches the strong and wide UV absorption feature observed on Ceres. Laboratory measurements [18] do not find any good match to the UV spectrum of Ceres either.

It is interesting to note that asteroid (2867) Steins, the only other asteroid with a reflectance measured at far-UV, has an almost flat spectrum within the 100-200 nm region, and an albedo of ~6% at 150 nm, which is more than a factor of 2 less than that of Ceres, and much lower than the visible albedo of Steins itself [19]. Steins, classified as an E-type asteroid [20], differs from Ceres and presumably contains significant amounts of iron-free minerals found in enstatite achondrite meteorites [21,22]. Its spectrum is almost featureless from the UV to near-IR except for an absorption band at ~500 nm [21], with a high visible albedo of ~40% [22].

While the completely different spectra of Ceres and Steins at UV are not totally unexpected because of their completely different compositions, it is extremely difficult, if not impossible, to interpret the far-UV spectra of these two asteroids based on our current knowledge of the UV spectroscopy of asteroids, simply because there is not much data available for other asteroids in this wavelength region.

Summary: 1. Far-UV images and spectra of Ceres were obtained with HST/ACS/SBC. 2. The albedo of Ceres at 145 nm is ~15%, much higher than its visible albedo, and almost 4 times higher than that at 280 nm. 3. The strong and wide UV absorption band of Ceres centered at 280 nm is confirmed. 4. The interesting UV absorption features of Ceres and Steins suggest that there are probably interesting, and potentially informative, spectral features in the UV on asteroids. More data of asteroids within this spectral region, as well as supporting laboratory measurements of minerals and meteoritic samples, are needed to help us understand the spectral properties of asteroids at UV wavelengths.

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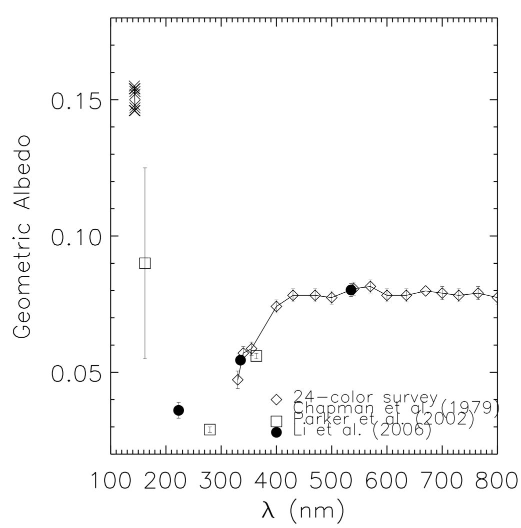

Fig. 1, UV spectrum of Ceres. The X's are the new data points from HST/ACS/SBC. The uncertainties are ~<20% (not shown in the plot). The absorption band at 280 nm appears to be confirmed.