Description of HST UV Slitless Reflectance Spectra of (1) Ceres

Prepare by Jian-Yang Li (Planetary Science Institute)
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Overview

This data collection contains the UV spectra extracted from HST observations using ACS/SBC, observation ID GO-11109. The observations were performed in PR130L slitless spectroscopy mode. Because Ceres is an extended source with an angular diameter of 0.68" at the time of the observations, the spectral resolution was degraded to various extent, and the spectral radiance level was enhanced, both depending on the width of Ceres in the dispersion direction.

In this dataset, we include, from each pixel on the disk of Ceres, the extracted raw spectrum, the derived radiance spectrum, and the reflectance spectrum, the average reflectance spectrum of Ceres from all pixels on Ceres, along with a list of the observation information for all original HST images.

Observations

The observations were made over three HST orbits with the same exposure sequence. A direct image of Ceres was acquired at the start of each orbit through the F125LP filter. Spectral observations followed at the same pointing through the SBC slitless prism PR130L in three identical exposures of 600 – 650 s each in each orbit.

The observations were performed on 2007 November 25 at 13:07:53 – 17:04:32 UT. Ceres was at 2.80 au from the Sun and 1.86 au from the Earth. Ceres was spatially resolved to about 21 pixels in diameter. The phase angle was 7.30 – 7.36 deg. The observing geometry is summarized in "HST observation information list" data product.

Data reduction

The reduction from 2-D spectral data array to 1-D spectrum grossly followed the standard process of data reduction of SBC slitless spectrum. However, because Ceres is an extended source, we had to manually perform all the spectral extraction and calibration. For the data from each orbit, we started with the original (geometric distortion uncorrected, _flt image) direct image and generated a mask for all the pixels inside the disk of Ceres. Those pixels are the references points for spectrum extraction.

We then summed all three spectral exposures in each orbit and normalized the sum by the total exposure time for spectral extraction. The spectral extraction followed the model described in HST ISR 0602 (Larsen et al. 2006). We extracted the spectra for all reference points inside the mask, and performed wavelength calibration, as well as the dispersion calibration following ISR 0602. This step results in 1135 extracted spectra within the disk of Ceres from three orbits. The raw spectra are archived in data product "Ceres UV raw spectrum" and saved in subdirectory dn/ with file names suffixed by '_dn'. The filenames of extracted spectra have a format of "spec_0x_yyy.tab", where x is the number of orbit (1, 2, or 3) from which the particular spectrum is extracted, and yyy is the index (starting from 0) of the reference pixel corresponding to each spectrum. Each spectral file lists the wavelength (Å), counts (DN/s/Å), error (DN/s/Å), the band boundary in the short and long wavelength sides (Å).

We did not apply a flatfield in our process, because the spectra from different references points on Ceres' disk along the dispersion directly interfere with each other, rendering the flatfield process complicated. The interference degrades the spectral resolution depending on the width of Ceres' disk along the dispersion direction, which also invalidates the standard flatfield process for point sources. It also affects the absolute radiometric calibration of all the spectra.

After all the raw spectra were extracted, we applied radiometric calibration to all of them. The responsivity curve from STScI website (ACS.SBC.PR130L.Cycle13.2.sens.fits) was used to convert all extracted spectra to intensity spectra in units of [W/(m^2 nm sr)]. The error of extracted raw spectra and the error of sensitivity spectra are combined following standard error propagation. Then we use a high-resolution solar spectrum, SUSIM (VanHoosier et al. 1988, Lean et al. 1992) to convert all radiance spectra to the spectra of radiance factor. The intensity spectra are archived in data product "Ceres UV radiance spectrum" and stored in radiance/ with file names suffixed by '_rad'. The reflectance spectra are archived in data product "Ceres UV reflectance spectrum" stored in reflectance/ with file names suffixed by '_iof'. No uncertainty for the solar spectrum is available. The files in the radiance/ and reflectance/ subdirectories follow similar naming convention as for the raw spectra in dn/ subdirectories except for the additional '_rad' and '_iof' suffix, respectively, and these files correspond to the spectra of the same filenames in the proceeding calibration steps.

The final step is to take the average of all reflectance spectra to represent the average spectrum of Ceres. First, we take the averages of wavelengths from all individually extracted spectra as the wavelengths of the averaged spectrum. Then we interpolate both the spectra and the associated uncertainties at the wavelengths of average spectrum, and take weighted average of all spectra following error propagation principles to calculate the average spectrum and associated errors. The final average reflectance spectrum is archived in data product "Average Ceres UV spectrum", and the plot of the average spectrum is shown in Fig. 1.

Quality assessment

The spectral resolution was degraded by the width of Ceres along the direction of dispersion, which was up to 20 SBC pixels across at the time of our observations. The absolute radiometric calibration also suffers from the spectral convolution from different points on Ceres along the direction of dispersion. We did not remove the flux from those interfering pixels when converting raw counts to flux for each spectrum, and therefore the absolute scale of reflectance is not reliable. The lack of flatfield is probably only a small contributor to the radiometric calibration compared to the effect of spectral convolution of a large extended source. Due to the spectral

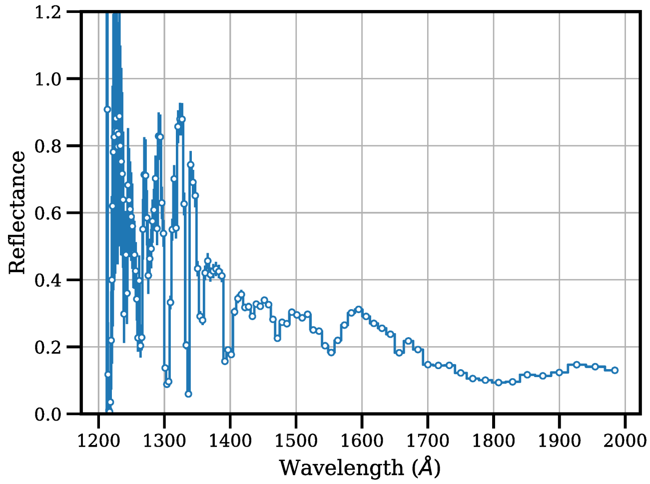

Fig. 1. Average Ceres spectrum in the UV derived from HST/ACS/SBC observations as archived.

resolution degradation and the uncertainty in the absolute flux calibration, the final averaged reflectance spectrum of Ceres is only good in its gross shape. All small spectral features of <~1000 Å are unreliable.

Our process to produce the average spectrum of Ceres from observations is highly simplified. A possibly better approach is to use spectral deconvolution to fit the average Ceres spectrum. Specifically, we should assume an initial reflectance spectrum of Ceres for all the pixels inside its imaged disk, and then use the solar spectrum and sensitivity curve to calculate the instrumental spectra in DN/s/pixel for each reference point. Then inverse flatfield is applied to these spectra for their particular locations in the detector, and they are combined to simulate the 2-D spectral image as observed. An iterative process should be taken to adjust the initial Ceres spectrum until the best fit to the observed spectral image is achieved. We did not have sufficient funding from STScI to support us to implement this complicated approach.

The reflectance spectrum is also affected by solar spectrum used. For the quality of solar spectrum, users can refer to the references of SUSIM solar spectrum.

References:

VanHoosier, M.E., Bartoe, J.-D. F., Brueckner, G. E., and Prinz, D. K., 1988. Absolute Solar Spectral Irradiance 120 nm-400 nm (Results from the Solar Ultraviolet Spectral Irradiance Monitor--SUSIM--Experiment on Board Spacelab 2). Astro. Lett. and Communications 27, 163-168.

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