2002 HST Calibration Workshop
Space Telescope Science Institute, 2002
S. Arribas, A. Koekemoer, and B. Whitmore, eds.

Removing Fringes from STIS Slitless Spectra and WFC3 CCD Images

E. M. Malumuth,[1] R. S. Hill,[1] T. Gull, B. E. Woodgate, C. W. Bowers, R. A. Kimble, D. Lindler,[2] R. J. Hill,[1] E. S. Cheng, D. A. Cottingham,[3] Y. Wen,[1] and S. D. Johnson[3]

Laboratory for Astronomy and Solar Physics, Code 681, NASA's Goddard Space Flight Center, Greenbelt, MD 20771

Abstract. We have developed a model that allows us to defringe slitless 2-dimensional spectra taken with the Space Telescope Imaging Spectrograph (STIS). An IDL tool has been developed which allows the user to defringe any spectrum obtained with the G750L grating on STIS. This technique has been employed to model the fringing on Wide Field Camera 3 (WFC3) flight candidate CCDs.

1. Introduction

Interference fringes are an annoying fact of life for many astronomical CCD detectors; the Space Telescope Imaging Spectrograph (STIS) and Wide Field Camera 3 (WFC3) CCDs are no exception. Fringes are caused by the interference of the incident and internally reflected beams within the thin layers of the CCD. The interference can be constructive or destructive within the CCD detection layer, leading to strong variations of the detection efficiency as a function of wavelength and local CCD thickness.

Fringing is not significant at wavelengths below $\sim$ 7000 Å where the absorption path length in silicon is less than the thickness of the CCD detection layer, but it becomes a serious issue at near-infrared wavelengths.

As reported previously (Malumuth et al. 2000, Malumuth et al. 2002), STIS CCD fringing can be modeled as an instance of multilayer thin-film interference using the Fresnel equations and the formalism of Windt (1998). The modeling requires a detailed knowledge of the CCD's physical structure (i.e., how many and what materials make up the stack). We then solve for the physical parameters (thickness and interfacial roughness) of each layer for each pixel. For the STIS CCD, we found that we could keep all of the parameters constant except for the thickness of the detection layer of the CCD.

In this paper we concentrate on how to use the results of the model fitting to defringe STIS slitless spectra. We also show that the same formalism and data obtained in the Goddard Space Flight Center's (GSFC) Detector characterization Laboratory (DCL) is being used to model the fringing of the WFC3 flight candidate CCDs.

2. STIS Slitless Spectra

STIS slitless spectra are usually obtained as image, spectral image pairs. Figure 1 is an example of a slitless spectral image pair taken as part of the STIS parallel program. The image, spectral image pair is shown in the IDL widget SLWIDGET (Lindler 1998) which can be used to extract the

[1]Science Systems and Applications, Inc.

[2]Sigma Space Corp.

[3]Global Science and Technology, Inc.

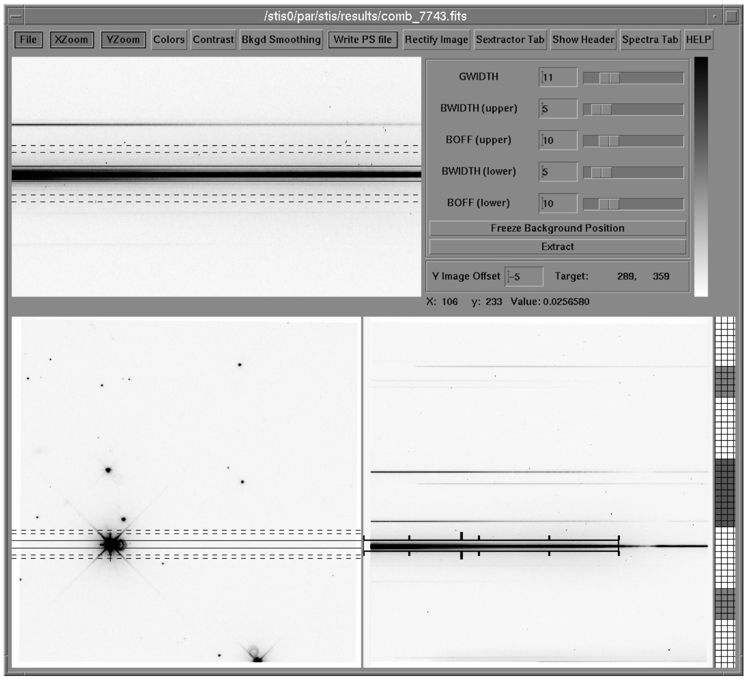

Figure 1. A image, spectral image pair shown in SLWIDGET.

spectrum of any object in the field. The image is needed so that we will know where in the field of view the object was located when the spectral image was taken. This is necessary to determine the wavelength scale.

3. Using The Model

The core of the model is a program that solves the Fresnel equations for a given pixel. The IDL procedure (LAYERS) is based on the formalism of Windt (1998) and is a function of the wavelength on the pixel, the number of layers in the CCD, the index of refraction and absorption coefficient of each layer at that wavelength, the thickness of each layer, and the "roughness" of the boundary between each layer (expressed as a diffusion distance). The function returns the transmission and the absorptance for that pixel at that wavelength. The fringe amplitude at that wavelength for the given pixel is the normalized absorptance. Therefore, to defringe a given spectrum we need to know the following.

- The wavelength of light hitting each pixel used in the spectral extraction.
- The structure of the CCD, including the composition and thickness of each layer in the CCD.
- The index of refraction and absorption coefficient of each material in the CCD as a function of wavelength.

The details of how the structure of the CCD at each pixel was derived, as well as an adjustment to the index of refraction of silicon as a function of wavelength have been previously reported by Malumuth et al. (2002).

Given the above information a model of the fringing for an object anywhere in the field of view can be computed. The resulting model for a given set of pixels is a sensitive function of the wavelength of the light on that pixel. Thus, a wavelength error in the spectral extraction of only a few angstroms can result in a poor fringe correction. Figure 2 shows how a shift of ± 10 Å effects the fringe location.

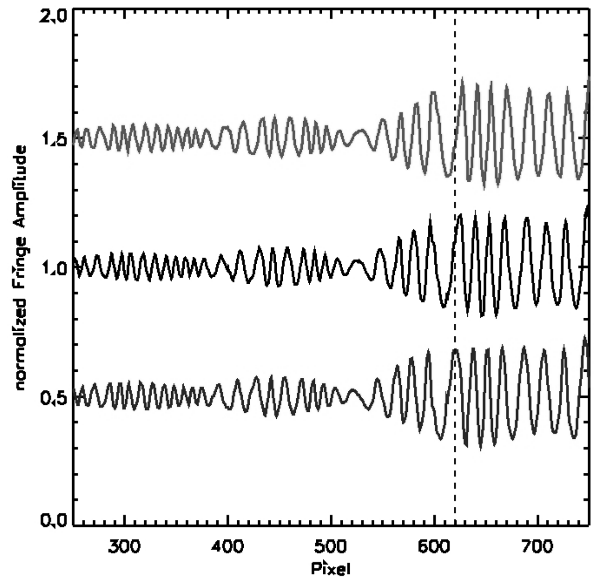

Figure 2. Three fringe models for the spectrum of the star shown in Figure 1. The top line is for a wavelength shift of -10 Å, while the bottom line is for a shift of +10 Å.

3.1. STIS Spectra Defringing Tool

An IDL widget tool (see Figure 3) brings all of the elements together to allow the user to defringe an extracted spectrum.

The user reads in the extracted spectrum in the form of a structure contained in a FITS table. The structure should include the wavelength vector, the flux vector, and the CCD location where the extraction was done. This maps the wavelength to pixel location.

The widget reads in the tables of the optical properties (index of refraction and absorption coefficient as a function of wavelength) of the materials in the CCD, the thickness vector, the roughness vector, and the map of the thickness of the detection layer as a function of pixel location.

The widget will normalize the spectrum by fitting a spline to the spectrum and dividing by the result. The normalized spectrum is displayed in the upper right window.

The user presses the "Find Wavelength" button. The widget will calculate 11 model fringe patterns for the center row of the extraction using a slightly different wavelength scale for each. The user may control the wavelength scales by changing the "Wavelength Offset" and "Wavelength Step Size." The defaults are 0 Å for the offset and 2 Å for the step size. At each step the calculated fringe pattern is plotted on the normalized spectrum as a blue line (seen in Figure 3 as a thin black line). The normalized spectrum is divided by this "model" fringe pattern and the result is displayed in the lower window, and the signal to noise ratio is calculated between 8300 Å and 10000 Å. The S/N ratio is plotted as a function of offset in the small window on the left. After the eleventh wavelength offset position is finished a gaussian is fit to the S/N vs. offset plot to find the best offset.

A fringe model is calculated for the best fit wavelength offset and divided into the flux calibrated spectrum and displayed in the lower window. If the user wishes, a full fringe model using all of the rows in the extraction may be calculated at this time by pressing the "Full Fringe Extraction" button. The defringed spectrum can be saved in a fits table using the "save" button.

4. WFC3 Fringing

The WFC3 instrument being developed for the *Hubble Space Telescope* will have a UV/VIS channel which will include two 2051×4096 pixel thin backside illuminated CCDs similar to the STIS CCD.

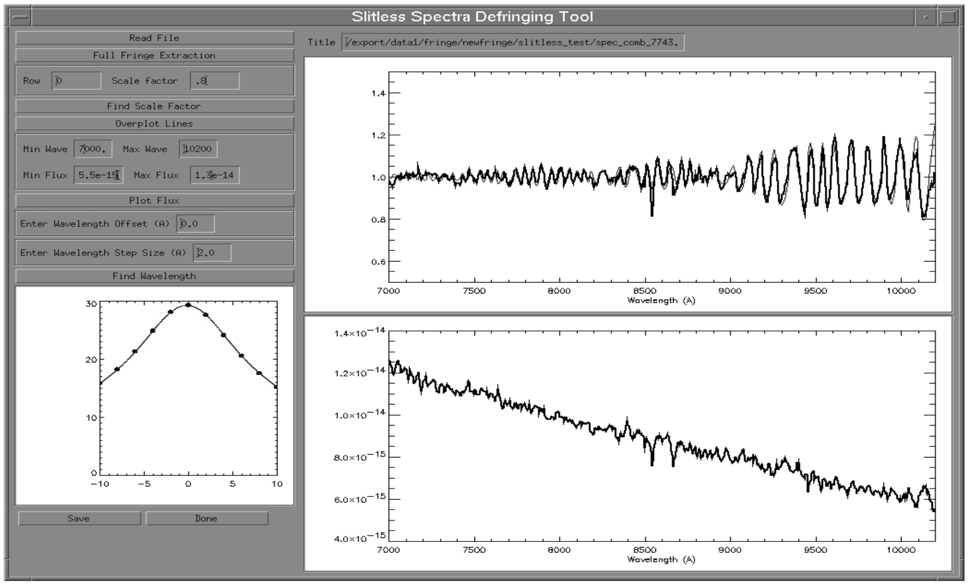

Figure 3. The IDL STIS Spectra Defringing Tool. The top plot shows the normalized spectra, with fringes, of the star shown in Figure 1. The thick line is the data, the thin line is the best fit model. The bottom right plot shows the resulting defringed spectra.

The techniques developed for modeling the STIS CCD are being applied to the flight candidate CCDs for WFC3, in the Goddard Space Flight Center's Detector Characterization Lab.

References

Malumuth, E. M., et al. 2000, *A Model for Removing Fringes from STIS Slitless Spectra*, BAAS, 197, 1204

Malumuth, E. M., et al. 2002, *Removing the Fringes from STIS Slitless Spectra*, PASP, in press

Malumuth, E. M., et al. 2002, *Model of Fringing in the WFC3 CCDs*, SPIE, in press

Windt, D. L. 1998, Computers in Physics, 12, 360