

# Spectroscopic Mode Peculiarities

---

Chuck Bowers (GSFC) and Stefi Baum (STScI)  
June 11, 1998

---

## ABSTRACT

*In this report we describe several spectroscopic mode peculiarities which can affect science observations, particularly when the goal is to detect very faint features or objects which are spatially nearby to very bright sources.*

---

## 1. Introduction

During SMOV and initial observations, a number of spectra have been obtained which show features which may affect the scientific goals of the observations, particularly when the science goals involve detection of faint features or objects spatially close to a very bright source. One class of spectroscopic images show diffraction structure of the PSF re-imaged at the various STIS detectors. A second class, commonly referred to as railroad tracks, display additional “spectra” displaced and parallel to the primary spectrum. A third class, commonly referred to as ghost spectra, occur in selected wavelength settings. Some examples and impacts are presented below.

## 2. PSF Re-imaging

The STIS corrector mirrors re-image the Optical Telescope Assembly (OTA) Point Spread Function (PSF) at an intermediate focus within STIS at the location of the slit wheel. This intermediate image is re-imaged to one of the detectors via the selected optic, either imaging or spectroscopic. Any PSF structure present in the slit plane image will be re-imaged at the detectors, however its appearance in a final spectrum or image depends on the selected mode and the slit or aperture used.

In the imaging modes, little PSF diffraction structure is apparent, since the available filters are typically relatively broad band, smoothing out any structure. The spectroscopic modes however, create a series of near monochromatic images at the detector plane and the PSF diffraction structure can be detected with the two dimensional STIS detectors.

*Case A: Spectrum of a calibrated stellar (point) source target.*

**Figure 1:** Dispersed diffraction rings in G140L, 52X0.05, point source observation.

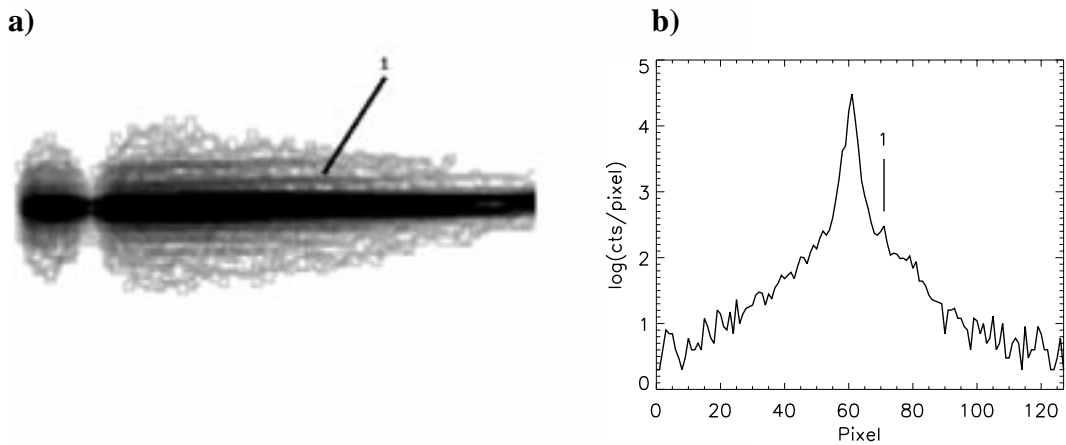
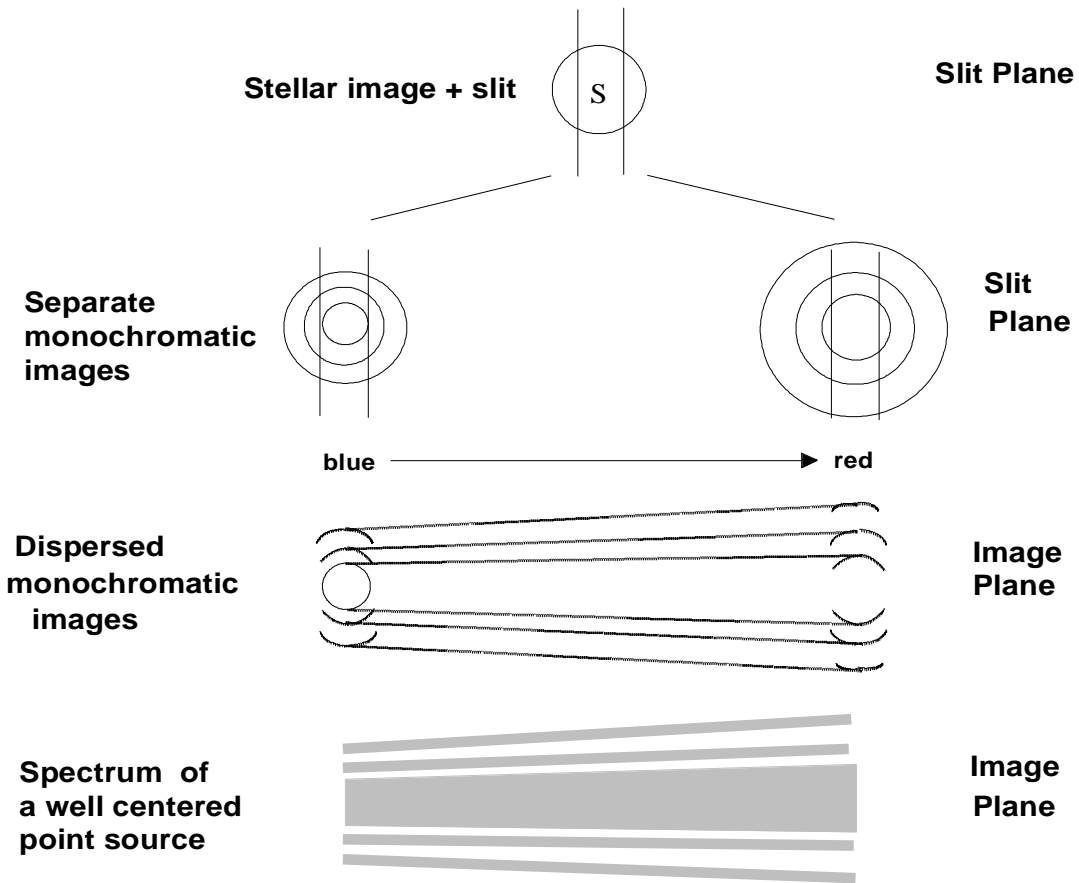


Figure 1a shows a typical stellar spectrum (1150–1700 Å) of a white dwarf taken for instrument calibration. The Lyman- $\alpha$  absorption feature is apparent near the left end. This image has been processed and log stretched to enhance the “fringes” seen above and below the stellar spectrum. These fringes are weak, diverge from the spectrum proportional to wavelength and are not present in the Lyman- $\alpha$  gap indicating they are connected with the source at the slit plane and are not the result of STIS internal scatter. Figure 1b shows a cross dispersion profile of the original image, cut near the center of the spectrum at about 1430 Å. The brightest fringe (labeled “1” in Figures 1a and 1b) is indicated.

Figure 2 is a cartoon illustrating how such fringes are created at the detector. At each wavelength, the portion of the PSF at the slit plane which passes the slit is re-imaged onto the detector. The envelope of all such PSF portions forms the complete image at the detector, as shown. The characteristic fringe separation, proportional to wavelength, is expected as the diffraction structure in the PSF increases with wavelength as shown. In the medium resolution modes, with much less bandpass than the low resolution modes, the tilt of the fringes is much less—they are nearly parallel to the primary spectrum.

**Figure 2:** Schematic showing creation of dispersed diffraction rings



The fringe visibility is decreased with increasing slit width. The cartoon illustrates this—as the slit broadens, more of a curved portion of the diffraction rings is transmitted. The envelope of these more curved sections is broader with lower contrast compared to the sharp segments visible with a narrow slit.

***Case B: Out of slit point source***

Figure 3 shows the spectrum (G140L) of a stellar source, in which the target was mislocated and therefore not nominally in the 52"x0.05" slit. While the target center was not located in the slit, the extended PSF structure did cover the slit opening and was transmitted and re-imaged at the detector plane. This image has been processed and log stretched to enhance the faint fringe structure which is apparent.

**Figure 3:** Dispersed diffraction rings from out of slit point source.

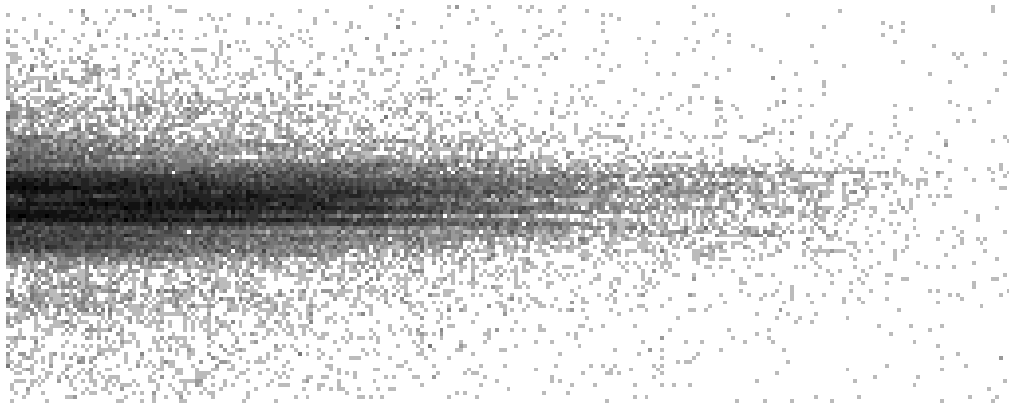


Figure 4a and b show a similar case in which the spectrum of a galaxy with a very bright core was deliberately obtained with the core nominally located 0.1" from the center of the 52X0.1 slit in the visible mode G750L. These images have been considerably processed and log stretched to enhance the fringe appearance. The spectrum appears to broaden and split toward the long wavelength end. Faint, divergent fringes are also apparent above and below the primary spectrum. A principal component of the "spectrum" consists of the upper and lower portions of the offset, first Airy ring, seen clearly separated at the long wavelength end of the spectrum. These two fringes converge at shorter wavelengths forming a single fringe which overlays the much fainter, off-core portion of the galaxy. The evident blueness of the core spectrum makes the combined blue fringes much brighter than the combination of the separated red fringes.

**Figure 4:** Further examples from out-of-slit point sources.

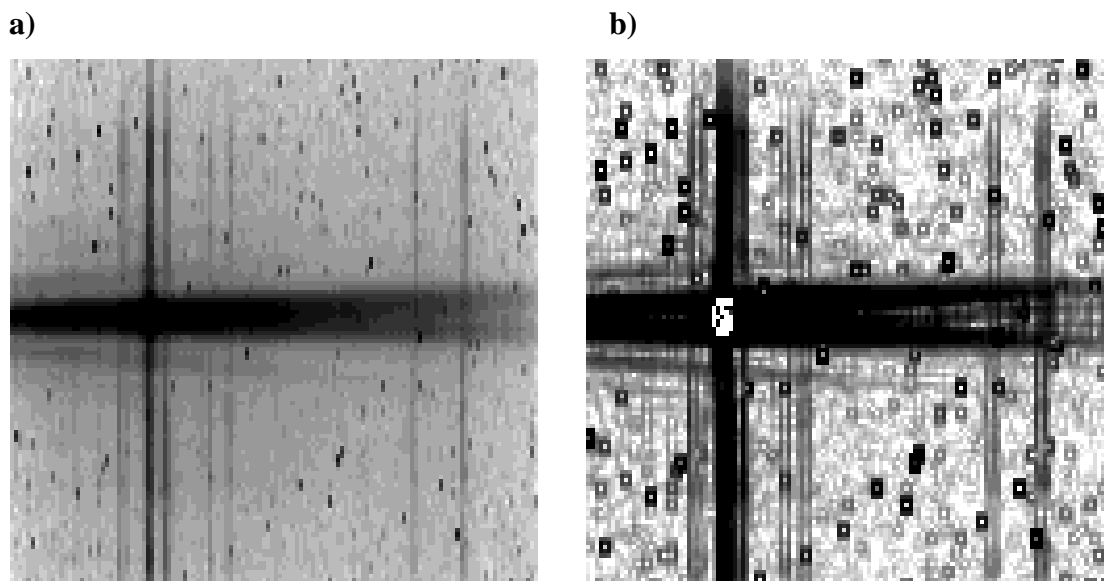
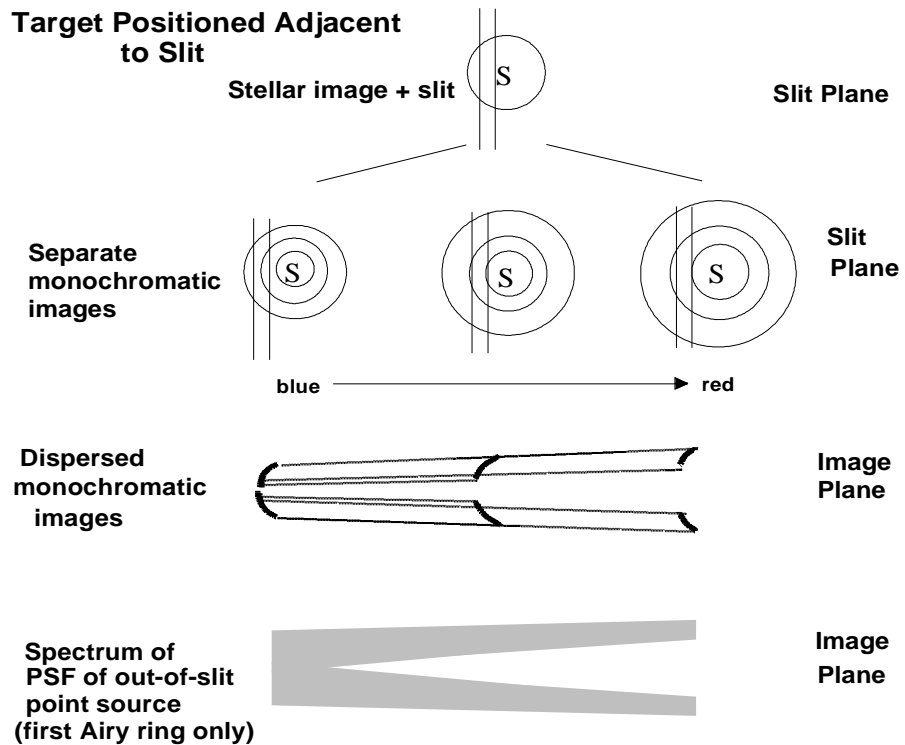


Figure 5 illustrates how a nominally out-of-slit point source target will generate the set of fringes shown in Figure 4. As the wavelength increases, the size of the Airy pattern increases but the target is at a fixed distance from the slit. This results in the first Airy ring sweeping across the slit as it expands with wavelength until only the upper and lower portion of the ring are within the slit causing the split fringe structure seen at long wavelengths.

**Figure 5:** Schematic of out-of-slit point source.



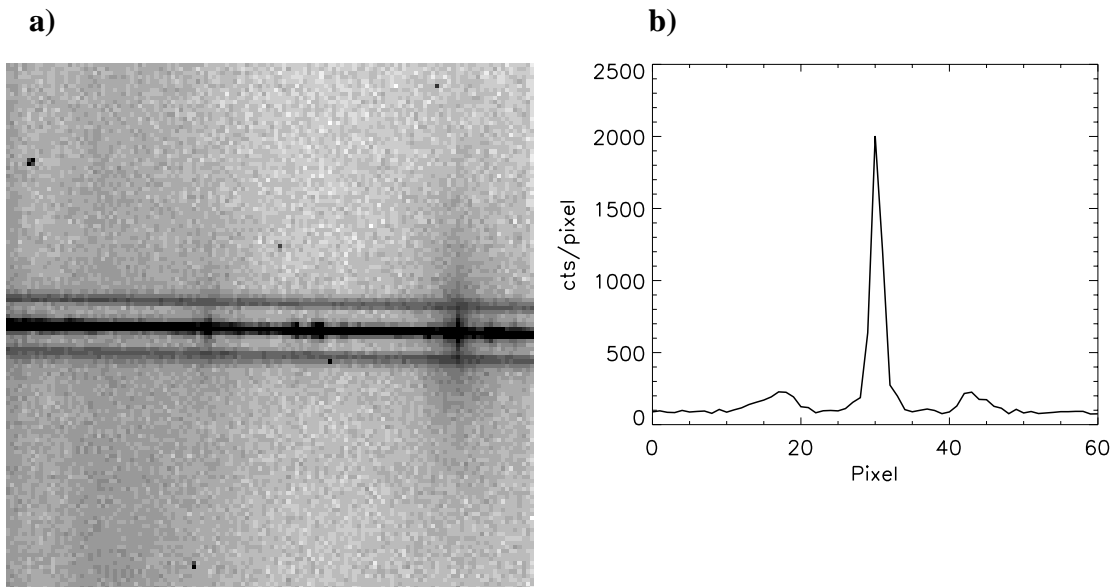
**Impact**

Diffraction structure in the PSF will set a limit to extracting spectra near a bright source. Blocking the bright source, either by using a coronagraphic aperture or by moving the bright source out of the slit does not remove the inherent, adjacent PSF/diffraction structure. In the case of a faint companion adjacent to a bright, primary source, note that the spectra of the primary and companion will be parallel while the PSF fringes will be tilted. This is especially true in the low resolution modes and may allow the unambiguous identification of a faint companion even in the presence of comparably bright PSF structure. Depending on the stability of the PSF they may be removable by obtaining a calibration spectrum of an isolated point source with the same spectral properties.

### 3. “Railroad Tracks”

Figure 6a shows a processed spectrum of a continuum lamp in mode G750M,  $\lambda_{\text{cen}} = 10363$  (no longer a supported setting) and using the 0.1x0.2 slit obtained during ground testing. Besides the spectrum, two adjacent, parallel, secondary spectra are seen symmetrically displaced about 13 pixels from the lamp spectrum. Figure 6b shows a cross dispersion profile illustrating the magnitude and shape of the spectra. The secondary spectra have peak intensities about 8% of the primary spectrum but are broader and asymmetric. This was the only example of this peculiar condition noticed during ground testing, however subsequent review showed one additional example also obtained during ground testing. This second case was a similar continuum lamp spectrum using G750M,  $\lambda_{\text{cen}} = 7795$ , with the same (0.1X0.2) slit. Secondary spectra were ~8% and 3% (peak intensity) of the primary peak intensity.

**Figure 6:** Ground test image showing railroad tracks: a) greyscale, b) cross cut.

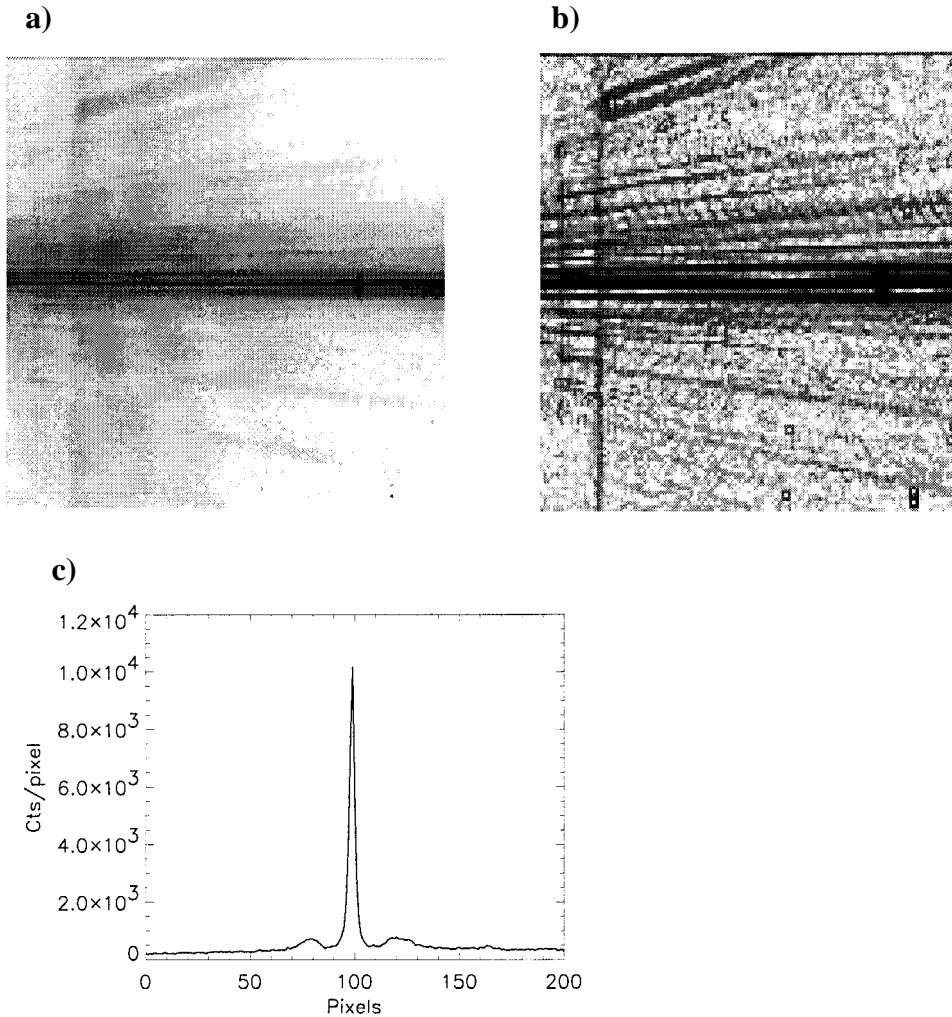


One similar example has been obtained in flight to date, with the UV mode G230LB and the CCD. The target was a very bright, very red star. Two views of the data, substantially processed to enhance faint fringes and other features, are illustrated in Figure 7.

The “railroad tracks” are seen parallel to the principal spectrum and separated from it by about 20 pixels. They are at a level of about five percent of the principal spectrum similar to the ground test results (Figure 7c). Also seen in this image are a series of faint, diffuse streaks which radiate from a common point off the frame and two, vertical borders. The streaks diverge from the position of the grating zero order image and are interpreted as due to STIS internal scatter due to this very bright, red source. The vertical borders

may be due to shadowing from internal baffles aligned in this direction. These internal scatter features have only been seen in this single image of an unusually bright, red source.

**Figure 7:** G230LB observation in 52X0.5 slit of a bright red star. a) and b) show two grey-scale and stretching, c) shows a cross cut.



The origin of these secondary spectra (“railroad tracks”) in these three observations is not known. The three cases observed have all been with the CCD: no MAMA examples have been obtained. Other observations in these modes under similar conditions have not shown such effects. In all cases, a red source was observed. The broad profile and relatively bright intensity of the secondary spectra suggest a multiple reflection instead of diffraction origin but no way of producing dual, symmetric features has yet been proposed which is consistent with these observations.

## 4. Relection Spectra

There are “ghost” spectra present for some of the wavelength settings, typically at very low levels ( $\leq 1\%$  of the prime, typically much lower) for the CCD modes. One example is provided in the G750M  $\lambda_{\text{cen}} = 5734$  setting, see Figure 8, where a ghost spectrum can be seen located roughly 40 pixels above the primary spectrum and inverted with respect to it. This setting has the most prominent known case of a ghost spectrum and the ghost spectrum is  $\sim 1.3\%$  of the brightness of the primary. The ghost spectrum is believed to arise from back reflections between the CCD and the order sorter. As we compile a complete list of the settings with ghost spectra, we will update information on the WWW STIS Foibles page.

**Figure 8:** G750M example of a ghost spectrum.

