An Introduction to FOS Scattered Light

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Abstract

The face plates on both the red and the blue sides of FOS allow the passage of red light into the detectors. Some of this red light is scattered and reaches the diode array, possibly from both the dispersive gratings and from other pathways. Data taken in the laboratory before the launch of *HST* shows a scattered light component that is slowly increasing with increasing wavelength. A comparison between spectra taken with the solar blind GHRS and with the FOS shows that the scattered light component dominates the count rate for late type stars.

I. Introduction

Characterization of scattered light is important, first to allow accurate calculations of exposure times needed to obtain a given signal-to-noise ratio, and, second so that the contribution from scattered light can be removed. The following is a brief introduction to observations of scattered light and to corrections for scattered light. For further discussions of the scattered light observed in the solar analog star 16 Cyg B, and the scattered light as a function of spectral type of the target, see Cunningham & Caldwell 1993 (this volume), and Rosa 1993 (and this volume), and Lyons et al. 1993.

II. Observations of Scattered Light

Laboratory measurements of FOS scattered light were obtained by illuminating the UV gratings with a tungsten lamp and a blocking filter (Blair, Davidson, Uomoto 1989). Since the filtered tungsten lamp produces no UV photons, any signal detected in such a configuration comes solely from scattered optical photons. Figure 1 shows the count rate observed on the blue side of FOS in the G130H, G190H, G270H, and G400H gratings when illuminated by a tungsten lamp with the GG395 blocking filter. The count rate increases from about one count per second at 1200Å to about three counts per second at 3000Å. In addition to this count rate which slowly increases with increasing wavelength, the G130H grating also shows a bump of scattered light at the long wavelength end, from 1400 to 1600Å. Table 1 gives the approximate percentage of peak intensity of red light scattered onto the blue gratings.

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Table 1: Percentage of Scattered Light From Ground-Based Tests [a]

Disperser	Detector	% Scattering	Notes
G130H	Blue	0.01	sharp rise at 1600Å
G190H	Blue	0.01-0.02	rises towards the red
G270H	Blue	0.02-0.03	rises toward the red
G160L	Blue	0.05	
G190H	Red	<0.01	
G270H	Red	<0.02	
G400H	Red	<0.015	
G160L	Red	<0.1	

a. From Blair, Davidson & Uomoto (1989).

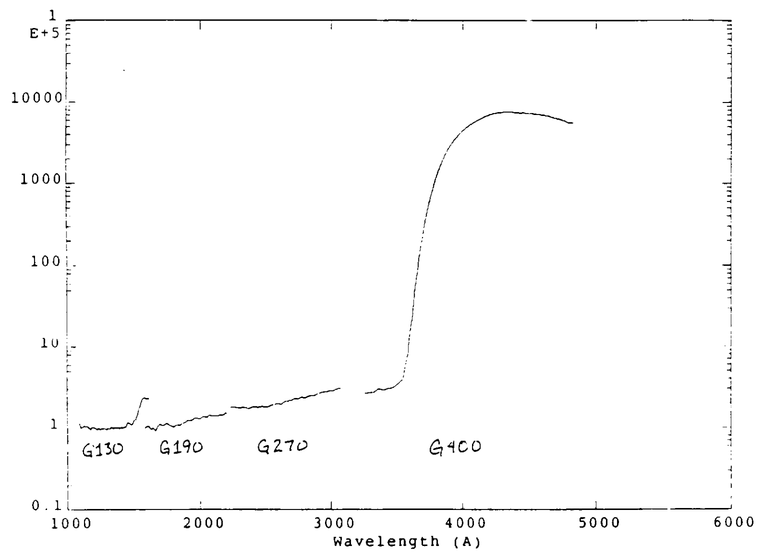

Figure 1: Laboratory measurements of scattered light observed on the blue side of FOS when illuminated by a tungsten lamp plus blocking filter (Blair, Davidson & Uomoto, 1989).

III. Calibration Program on Scattered Light

Calibration observations have recently been taken of late type stars previously observed with the side 1 of the GHRS, which is blind to photons with wavelengths longer than 1900Å. Figures 2, 3, and 4 show the FOS and the GHRS spectra of Gamma Draconis, α Orionis, and 16 Cyg B, respectively. The GHRS spectrum of Gamma Draconis (spectral type K4III, observed by Carpenter) shows mostly the sky lines (Lyα 1215Å and OI 1301Å), while the FOS spectrum is dominated by scattered light. The GHRS spectrum of α Orionis (M2I star, Carpenter 1991) shows both continuum flux and line emission. However, the FOS spectra are still dominated by scattered light. The third example, the solar analog 16 Cyg B, is discussed in detail in Cunningham & Caldwell (1993).

The scattered light in the three cases shows similar features; an upturn towards short wavelengths, a bump at 1465Å, and two “absorption features” between 1580 and 1600Å.

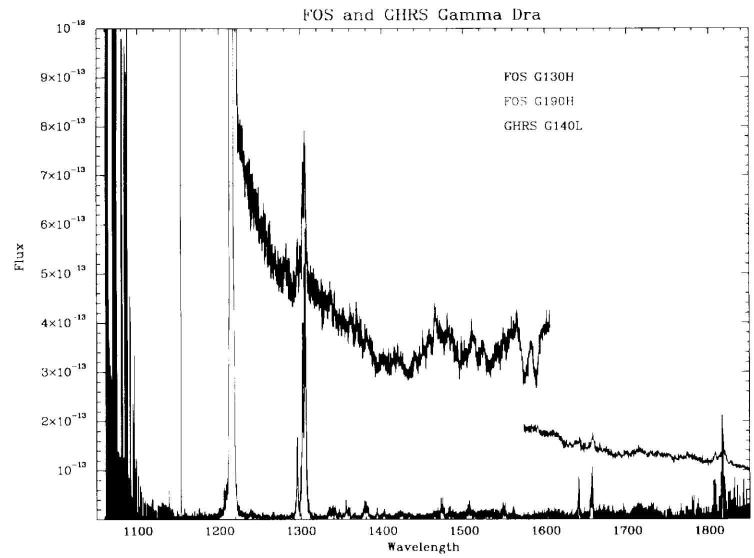

Figure 2: FOS spectra of the K4III star Gamma Draconis plotted on top, with the GHRS spectra plotted underneath. The GHRS spectra show no continuum flux and sky lines of Lyα and OI. The FOS spectra are dominated by scattered light.

IV. Correction for Scattered Light

A full correction for scattered light requires an understanding of the source of the scattering and whether the scattered light follows the light path through the diffraction grating or is reflecting from a baffle or some other obstruction in the light path (or whether the scattered light is from both sources). Also, a full correction requires a characterization of the wavelength dependence of the scattered light and a characterization of the dependence of scattered light on the incidence spectrum.

Simple Correction

For about half the gratings, a simple solution is available, as described in Kinney & Bohlin (1993). A subset of gratings (G160L, G650L, G780H, and the prism on the red side; G130H, G160L, and the prism on the blue side) contain regions with no sensitivity to the first order dispersed light because of their optical cutoffs. These regions can be used to get a direct measurement of the scattered light component for each individual observation by averaging the detected counts over the region of zero sensitivity, and subtracting that count rate from the total count rate. This method is currently being incorporated in pipeline extractions.

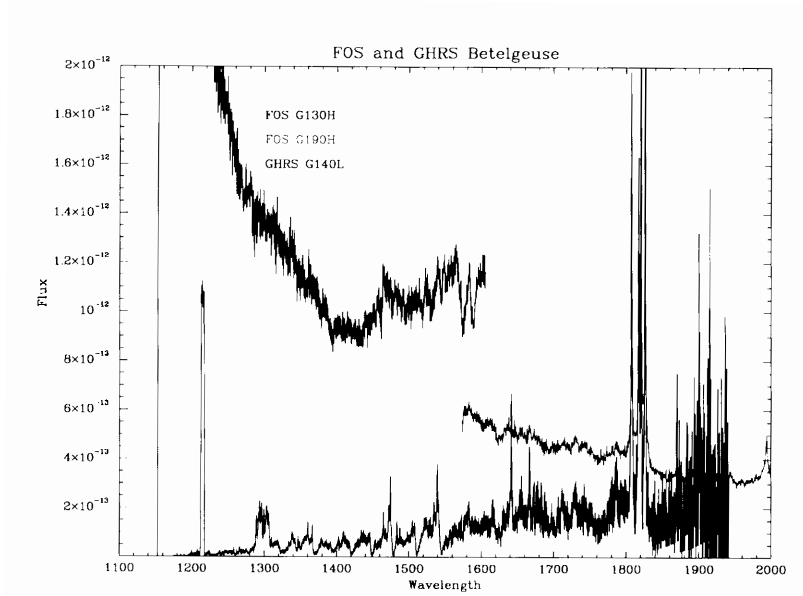

Figure 3: FOS spectra of Betelgeuse plotted on top with the GHRS spectra (Carpenter et al. 1993) plotted underneath. While the GHRS spectrum shows a number of features originating in the star , the FOS spectrum is again dominated by scattered light.

While using the zero sensitivity regions to directly measure the background improves the determination of the background, this method assumes that the background is constant with wavelength. The laboratory measurements of scattered light shows that the count rate of the background is only approximately constant with wavelength, as illustrated in Figure 5, a plot of the count rate of the spectrum of 16 Cyg B, which is dominated by scattered light. Note that the count rate is not wavelength independent.

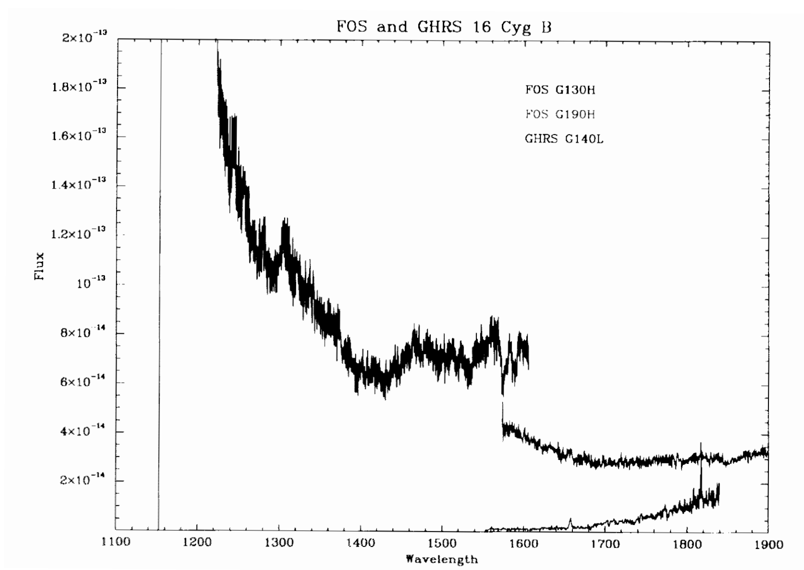

Figure 4: FOS Spectra of the solar analog 16 Cyg B plotted on top with a GHRS spectrum (Caldwell & Cunningham 1992) plotted underneath.

Robust Correction

A more robust correction must take into account the wavelength dependence of the scattered light, and the dependence on spectral type of the object, in a manner demonstrated by Caldwell and Cunningham (1992) and Cunningham and Caldwell (1993). Although such a characterization is not trivial, there is evidence that the scattered light is well behaved as a function of spectral type. Figure 6 shows the count rate as a function of spectral type as simulated by R. Gilmozzi and E. Kinney . Gilmozzi and Kinney have input stars of varying spectral type into the STSDAS simulator SYNPHOT to calculate the average count rate due to the bolometric luminosity of the stars. The count rate is then normalized with an FOS observation of a star of known spectral type. Upon normalization, the correlation has been verified by comparison observations of several additional stars with varying different spectral type. (See the Rosa contribution in this volume for a similar method based directly on observations of a wide range of objects.) These studies demonstrate that the count rates due to scattered light should be well predicted by spectral type.

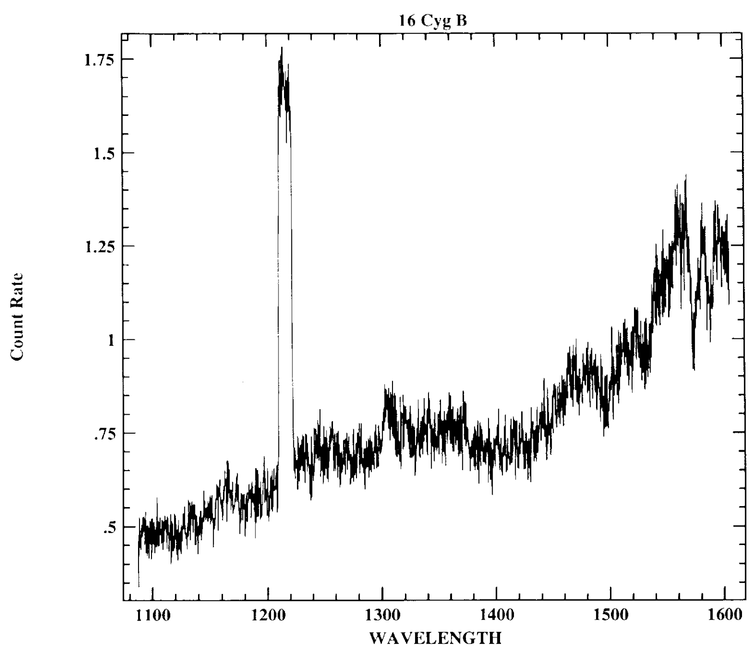

Figure 5: Count rate in the FOS, blue side G130H spectrum of the solar analog 16 Cyg B. Note that the scattered light which dominates this spectrum is not wavelength dependent.

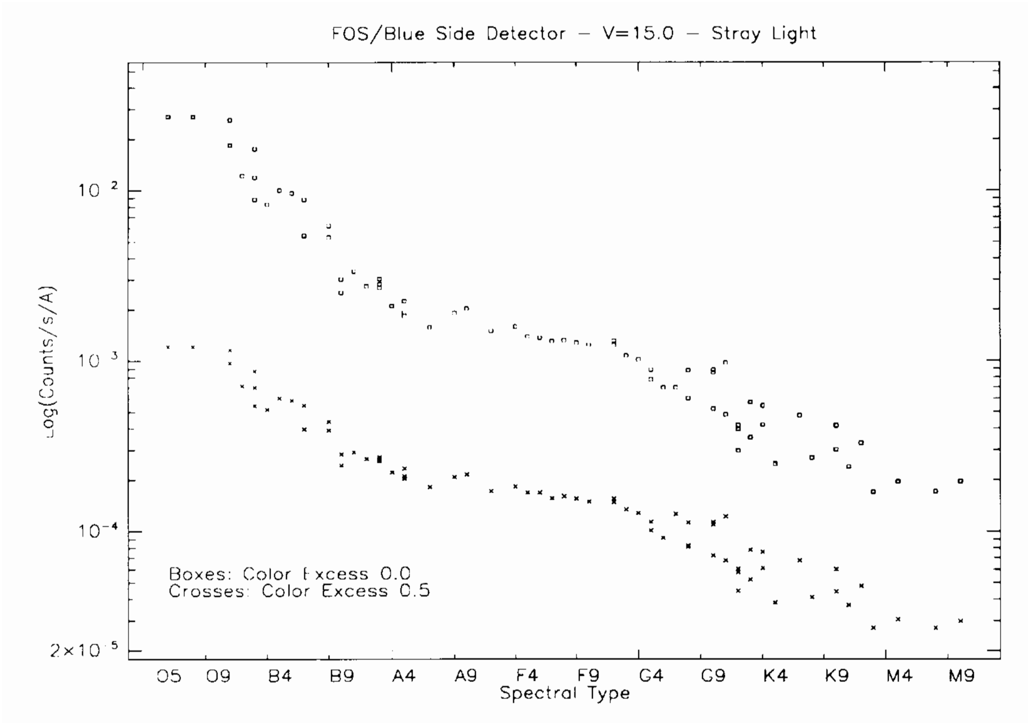

Figure 6: The count rate of scattered light is predicted by R. Gilmozzi and E. Kinney for the blue side of FOS as a function of spectral type assuming the star is at 15th magnitude.

References

Ayres, T .R. 1993, *Scattered Light in the G130H G190H Modes of the HST Faint Object Spectrograph*

Blair , W.P., Davidsen, A.F ., & Uomoto, A. 1989, *Scattered Red Light in the FOS* , CAL/FOS-058

Caldwell, J., & Cunningham, C.C. 1992, *Grating Scatter in the FOS and the GHRS* , SV Report

Carpenter , K., Robinson, R., Ebbets, D., Brown, A., Linsky , J. 1991, B.A.A.S., 23, 910

Cunningham, C.C., & Caldwell, J. 1993, *Grating Scatter in the HST Faint Object Spectrograph* , in the proceedings on the Calibration W orkshop, held at STScI, Nov. 15, 1993

Kinney , A.L., & Bohlin, R.C. 1993, *Background Due to Scattered Light* , CAL/FOS-103

Lyons, R.W ., Baity , W.A., Beaver , E.A., Cohen, R.D., Junkkarinen, V .T., Linsky , J.B., & Bohlin, R.C. 1993, *On-orbit sky background measurements with the FOS* , in SPIE Proc. V ol 1945 "Space Astronomical T elescopes and Instruments II", ed. Bely, P.Y. and Breckinridge, J.B. publisher SPIE Bellingham, W A, p. 232-243

Rosa, M.R. 1993, *Scattered Light in the FOS: An Assessment Using Science Data* , CAL/FOS-1 13