Scattered Red Light in the FOS

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ABSTRACT

Continuum lamp observations have been used to determine the fraction of incident long-wavelength photons scattered into the ultraviolet beam by the FOS dispersers. Except for the relatively unlikely combination of the G160L grating and red Digicon, the gratings show acceptable scattered light levels of about 0.02% of the peak red light intensity. Observations with the prism indicate a potentially high susceptibility to scattered red light (up to 1%), although the test exposures were heavily overexposed and this number is highly uncertain.

1. INTRODUCTION

Observations of a tungsten calibration lamp with colored glass blocking filters can be used to estimate the amount of red light scattered by the ultraviolet gratings in the FOS. Since the filtered tungsten lamp produces no ultraviolet photons, any signal seen with the ultraviolet gratings in place is from scattered visible and red photons.

2. OBSERVATIONS

The data were obtained in March 1988 at Lockheed using the YCSCTA procedure. The filters used were Schott WG230, WG295, GG395, and OG530 with transmission curves as seen in Figure 1. The reductions accounted for paired-pulse coincidence corrections and bad diodes, but dark current was not removed because it is not large enough to be a problem. Bandpass corrections for the grating observations were done using the grating dispersions tabulated by Ford [1], and the prism observations were corrected using an estimate of the local dispersion based on the appropriate wavelength array. All count rates here are per Å.

3. RESULTS–BLUE TUBE: G130H, G190H, G270H

The manufacturer's transmission curves (Figure 1) suggest that the the GG395 filtered observations should show a negligible count rate blueward of 3400 Å. This is not the case.

Figure 2 shows the count rates measured with the blue Digicon and grating G130H when the FOS is illuminated with a tungsten lamp covered with GG395, WG295, and WG230 filters. Also included is an unfiltered observation. In a perfect, non-scattering spectrograph, all but the unfiltered observation would show only negligible dark current. The count rate in all situations is considerably larger than dark, an indication that scattered light is reaching the detector.

In Figure 2, the upper three curves coincide and correspond to the the WG295, WG230, and unfiltered observations. The observation of the GG395 filtered lamp (lower curve in Figure 2), which allows the least amount of light into the spectrograph, shows a "spectrum" similar in shape to the others but with a lower count rate by a factor of two to three, depending upon which pixels are examined. The obvious implication is that the excess light seen in the other three observations is from photons between 3000 and 4000 Å (about the range between the blue cut-off wavelengths of the WG295 and GG395 filters) being scattered off the grating onto the detector. The long wavelength end (1600 Å) seems to be more susceptible, showing a factor of three increase in scattered light compared with a factor of two at the short wavelength end (1100 Å). Gratings G190H and G270H show the same characteristics except that the increase in scattered light with the GG395 observation does not show any color dependence.

Figure 3 shows observations of the lamp blocked with the WG295 and GG395 filters using gratings G130H (1100–1600 Å), G190H (1600–2300 Å), G270H (2300–3300 Å), and G400H (3300–4700 Å). Except for the G130H grating, the shapes of the curves below the filter cutoffs as well as the fractional excess light are the same. We see this as evidence that the excess signal is caused by near-UV (~3500 Å) photons being scattered onto the detector by the gratings.

Figure 4 is the difference of the two curves shown in Figure 3, showing the relative susceptibility of each grating to scattered light from the near ultraviolet. Photons from 2500–4500 Å are redistributed throughout the 1000–2300 Å range covered by gratings G130H and G190H. The figure shows that a continuous spectrum with a count rate of 10 kHz in the near ultraviolet (3500 Å), will be detected as scattered light in the 1000–2500 Å range at the 1–4 Hz (0.02–0.08%) level.

This example is atypical because the source of scattered photons is limited to a 2500–4500 Å bandpass. Except for intermediate redshift quasars, few astronomical objects observable by HST will have this type of spectral energy distribution. Quasars with Ly-α redshifted into the 3000–4500 Å range will probably be too faint to be affected by scattered light contamination at the 1% level, and most other objects with strong emission in this range will be bright enough to make this component of scattered light unimportant.

Perhaps a more interesting case is the observation of a red star with ultraviolet gratings. The 4000 Å cutoff in late type stars makes the GG395 observations a reasonable model of the type of scattered light problems we might expect from cool star observations. Figure 5 shows the GG395 filtered lamp observations, in which we see that the three ultraviolet gratings G130H, G190H, and G270H are susceptible to scattered visible light at the 0.01–0.03% level, assuming negligible dark current. The redder distribution of photons is not as easily scattered into the detector by the ultraviolet gratings.

G160L

Figure 6 shows the observations of the filtered lamp with gratings G160L, G270H, and G400H. The G160L low dispersion grating scatters much more visible light than its higher dispersion counterparts, G130H and G190H. With the GG395 filter in place, the scattered light level is about 0.05% of the peak count rate in the visible. It also prefers scattering red photons, since the relative signal levels of the WG295 and GG395 observations (50%) is smaller than the factor of 2–3 seen in the other gratings.

Prism

Observations with the WG295 and GG395 filters through the prism are shown in Figure 7. The red light count rate is not measured directly because the data overflowed the counters, but based on the observed 8-fold overflow, the peak count rate is estimated to be about 10 kHz, making the scattered light level between 0.1% and 1%, depending upon which area of the detector is being considered.

4. RESULTS–RED TUBE: G190H, G270H, G400H

Figure 8 shows observations of the tungsten lamp blocked with GG395 and OG530 filters taken with the red Digicon and gratings G190H, G270H, G400H, and G570H. The effect seen is the same as with the blue tube, with the amount of scattered light increasing when more light is placed on the gratings. Figure 9 shows the difference of the curves in Figure 8 from which we infer that photons in the 4000–5500 Å range are scattered at the 0.01 to 0.05% level from gratings G190H, G270H, and G400H. Unfortunately, quantitative measurement of the fraction of light scattered from the 5500–8500 Å range is not possible because the count rates in this region were too high to be measured accurately. Upper limits are 0.01–0.2% for gratings G190H and G270H, and 0.15% for grating G400H.

G160L

Figure 10 shows the GG395 and OG530 filter observations taken with the G160L grating. Also shown are the G270H, G400H observations in both filters, and one G570H for reference. The G160L observation is obviously a scattered light detection, as the red Digicon is insensitive blueward of about 1600 Å. The peak count rate cannot be measured in the G570H observation because the counters have overflowed an unknown number of times, but an upper limit to the scattered light in the G160L grating must be 0.1%.

Prism

Prism observations using the red Digicon are shown in Figure 11. Scattered red light in the ultraviolet region of the spectrum is clearly present, although a good quantitative measure is not possible because the count rate in the red and visible part of the spectrum is not reliably measured. An estimate based on the 18-fold overflow seen in the WG230 observation is that the scattered light in the ultraviolet portion is approximately 1%. This unreliable number is larger than that seen with the prism and the blue Digicon, and is consistent with the larger bandpass of the red tube.

5. SUMMARY

The following table summarizes the scattered light performance for the different dispersers based on the GG395 filtered observations.

Scattered Red Light

Disperser	Digicon	% scattering	Notes
G130H	Blue	0.01	rises sharply at 1600 Å
G190H	Blue	0.01–0.02	rises towards the red
G270H	Blue	0.02–0.03	rises towards the red
G160L	Blue	0.05	
Prism	Blue	0.1–1.0	uncertain
G190H	Red	≤ 0.01	
G270H	Red	≤ 0.02	
G400H	Red	≤ 0.15	
G160L	Red	≤ 0.1	
Prism	Red	1.0	uncertain

Generally, scattered red light contamination of ultraviolet spectra is small. The low dispersion grating G160 with the red Digicon is affected at a relatively high level (0.1%), but this combination is not one that is likely to be used often. Observations with the prism may also be affected significantly, but the current tests do not allow a good measurement of the scattered red light because the test observations were extremely overexposed.

REFERENCE

[1] Ford, H. C. 1985, *Faint Object Spectrograph Instrument Handbook.*

FIGURES

1. Transmission curves for the filters used in these observations.
2. Grating G130H, blue Digicon observations. The lower curve is with the GG395 filter. The upper three curves are with WG295, WG230, and no filter.
3. Observations of the filtered tungsten calibration lamp through four gratings. Some of the excess light between 2500 and 3500 Å is scattered into the 1000 to 2500 Å region.
4. The difference of the upper and lower curves in Figure 3, showing the spectral distribution of the excess near ultraviolet light that caused the excess scattered light in the G130H and G190H observations.
5. These are the same as the lower curve in Figure 3.
6. Like Figure 3, but with the low dispersion grating G160 instead of G130H and G190H.
7. Blue Digicon observations using the prism and WG230 and GG395 filters.
8. Red Digicon observations with GG395 and OG530 filters.
9. The difference of the upper and lower curves in Figure 8.
10. Like Figure 8, but with the low dispersion grating G160L instead of G130H and G190H.
11. Red Digicon observations with the prism.

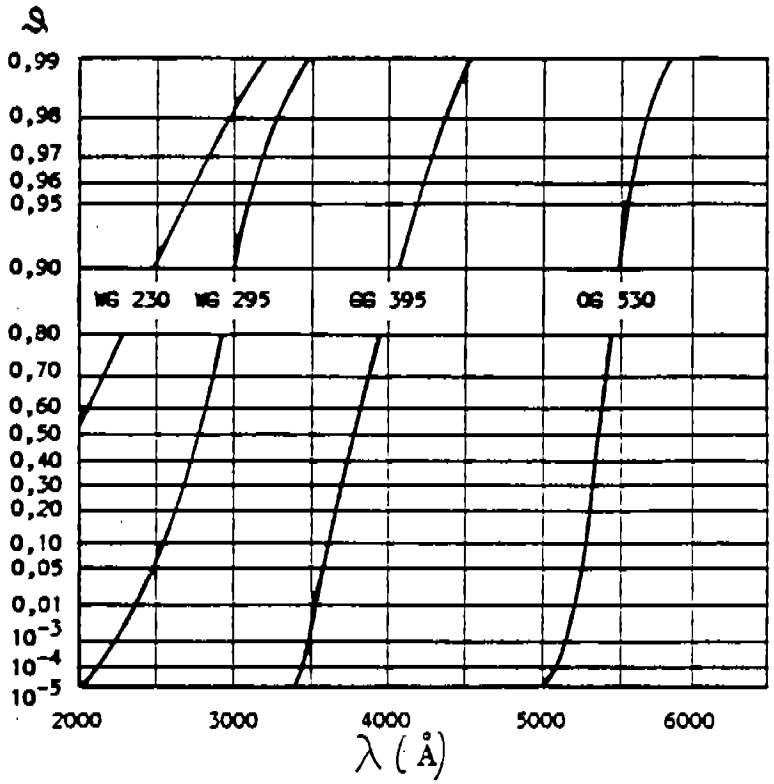
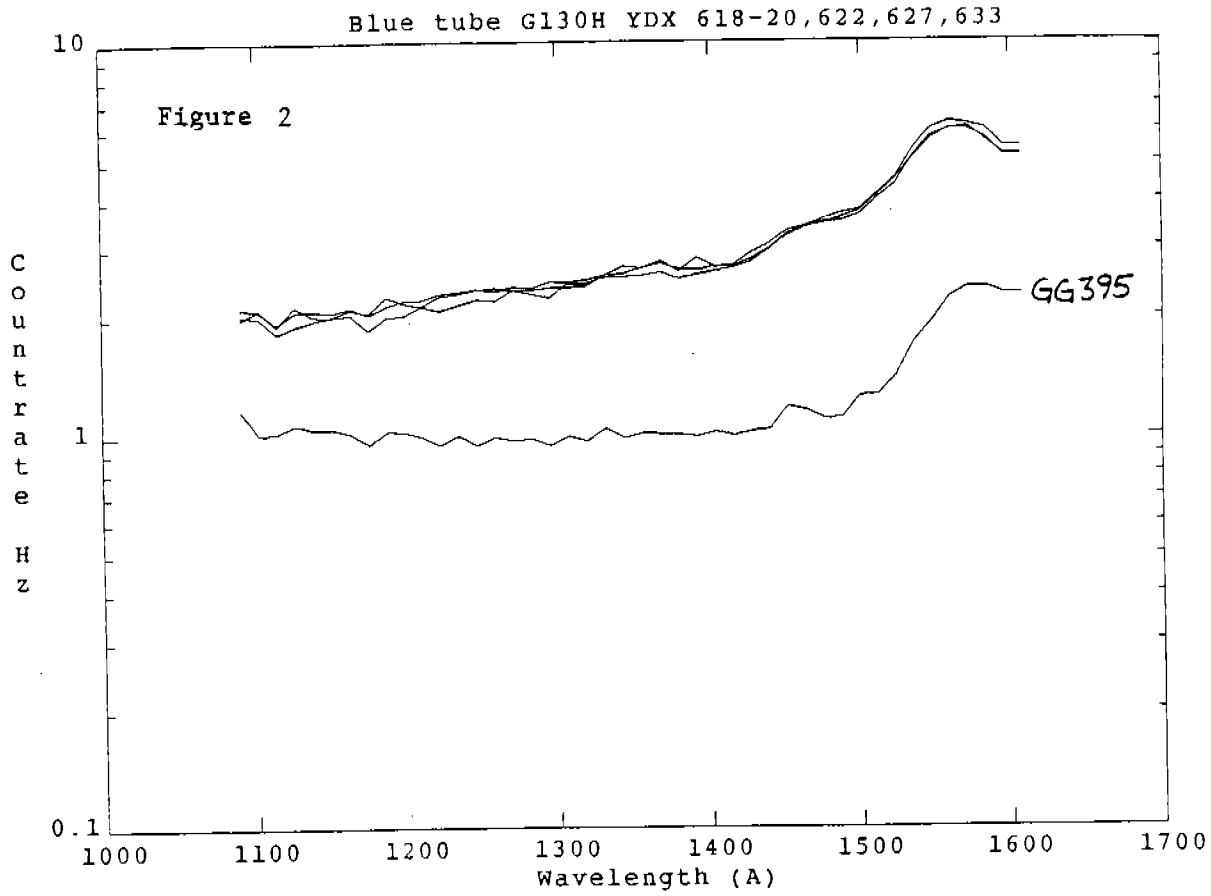
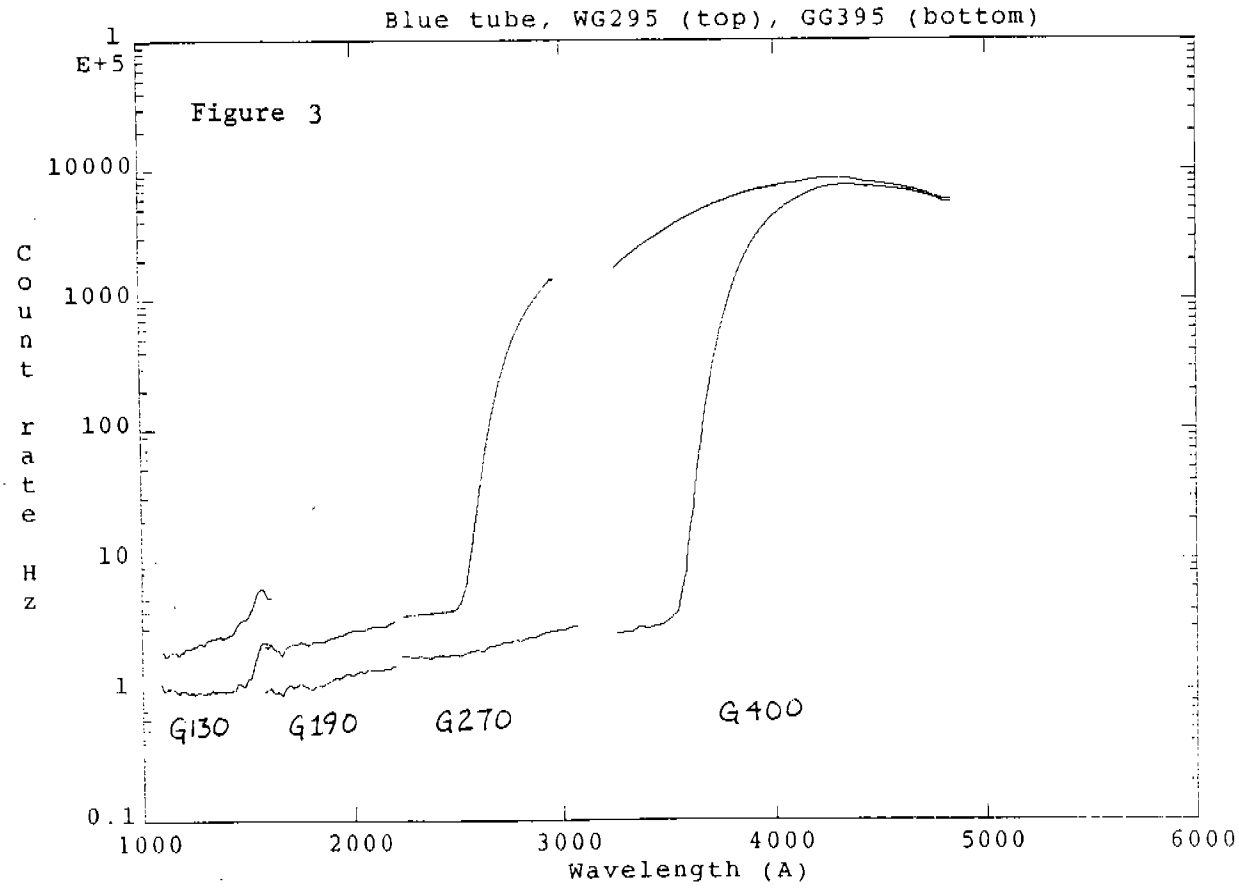
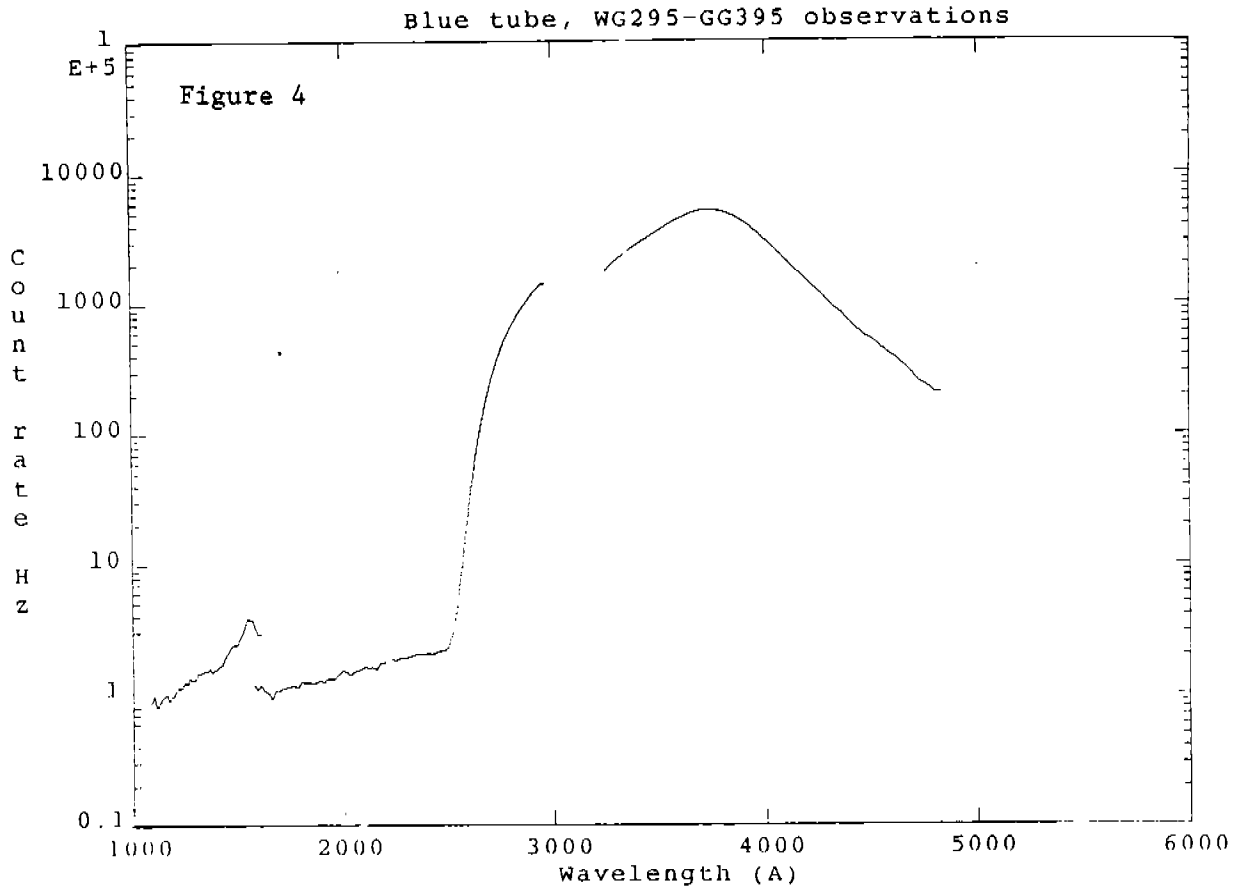
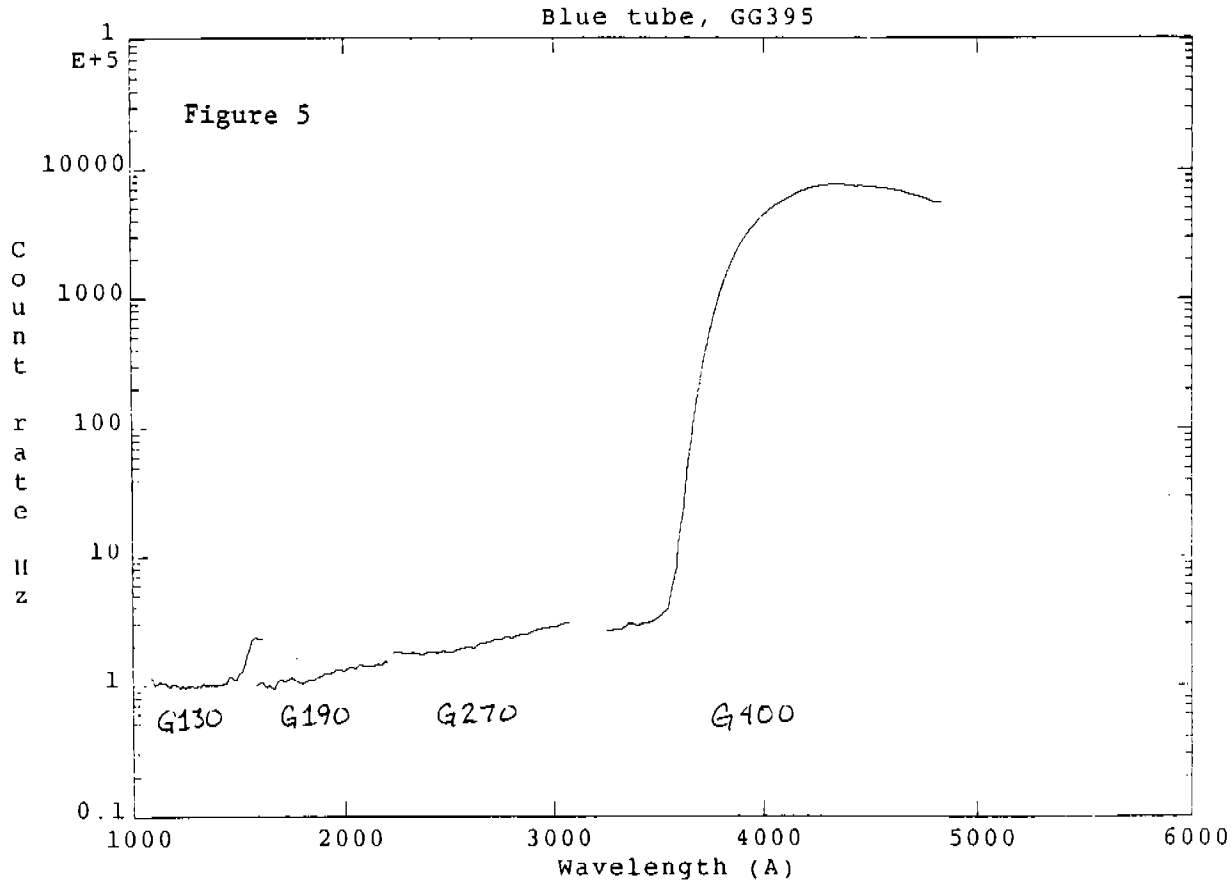

τ
0,99
0,98
0,97
0,96
0,95
0,90
0,80
0,70
0,60
0,50
0,40
0,30
0,20
0,10
0,05
0,01
10⁻³
10⁻⁴
10⁻⁵
WG 230
WG 295
GG 395
OG 530
2000
3000
4000
5000
6000
λ (Å)

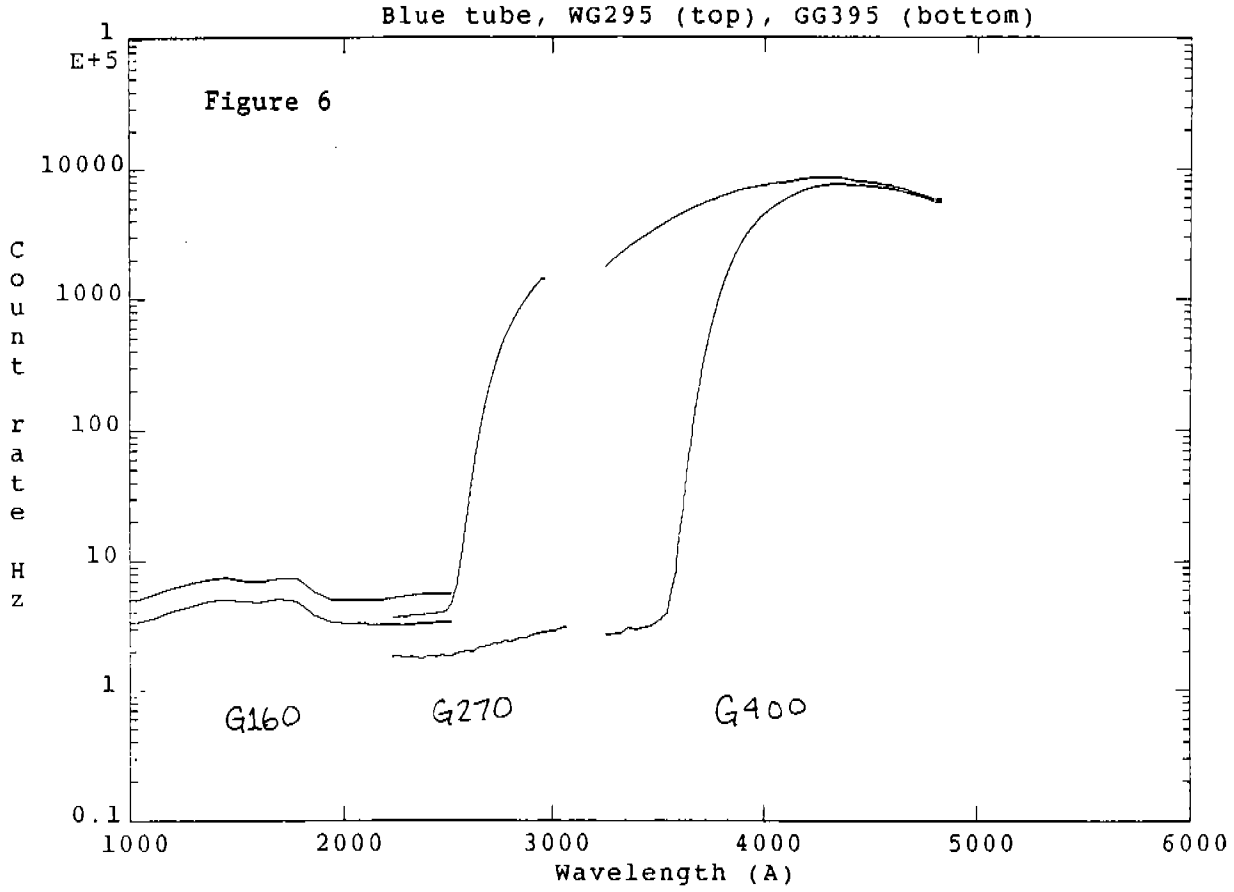
FIGURE 1

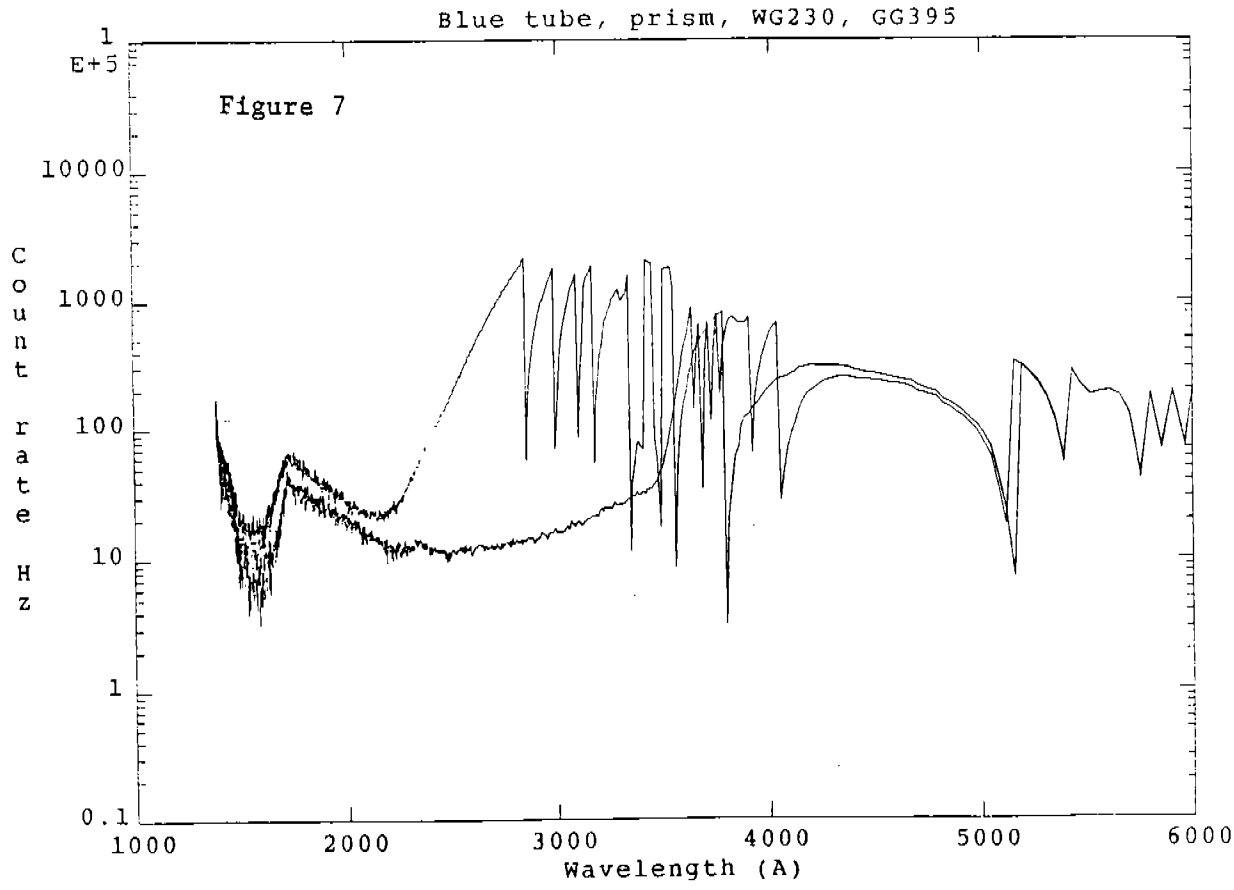

Blue tube G130H YDX 618-20,622,627,633
Figure 2
GG395
Countrate Hz
10
1
0.1
1000
1100
1200
1300
1400
1500
1600
1700
Wavelength (A)

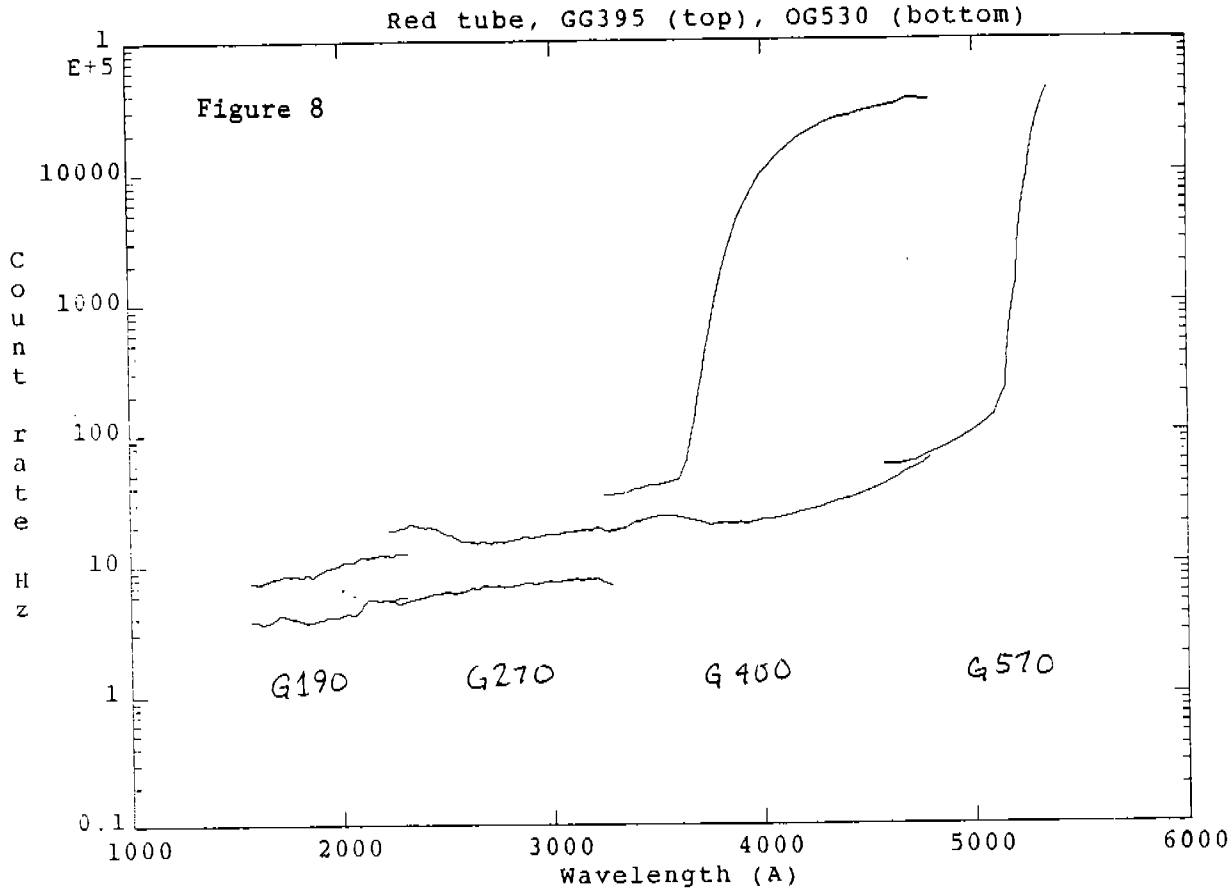

Blue tube, WG295 (top), GG395 (bottom)
Figure 3
Count rate Hz
1 E+5
10000
1000
100
10
1
0.1
G130
G190
G270
G400
1000
2000
3000
4000
5000
6000
Wavelength (A)

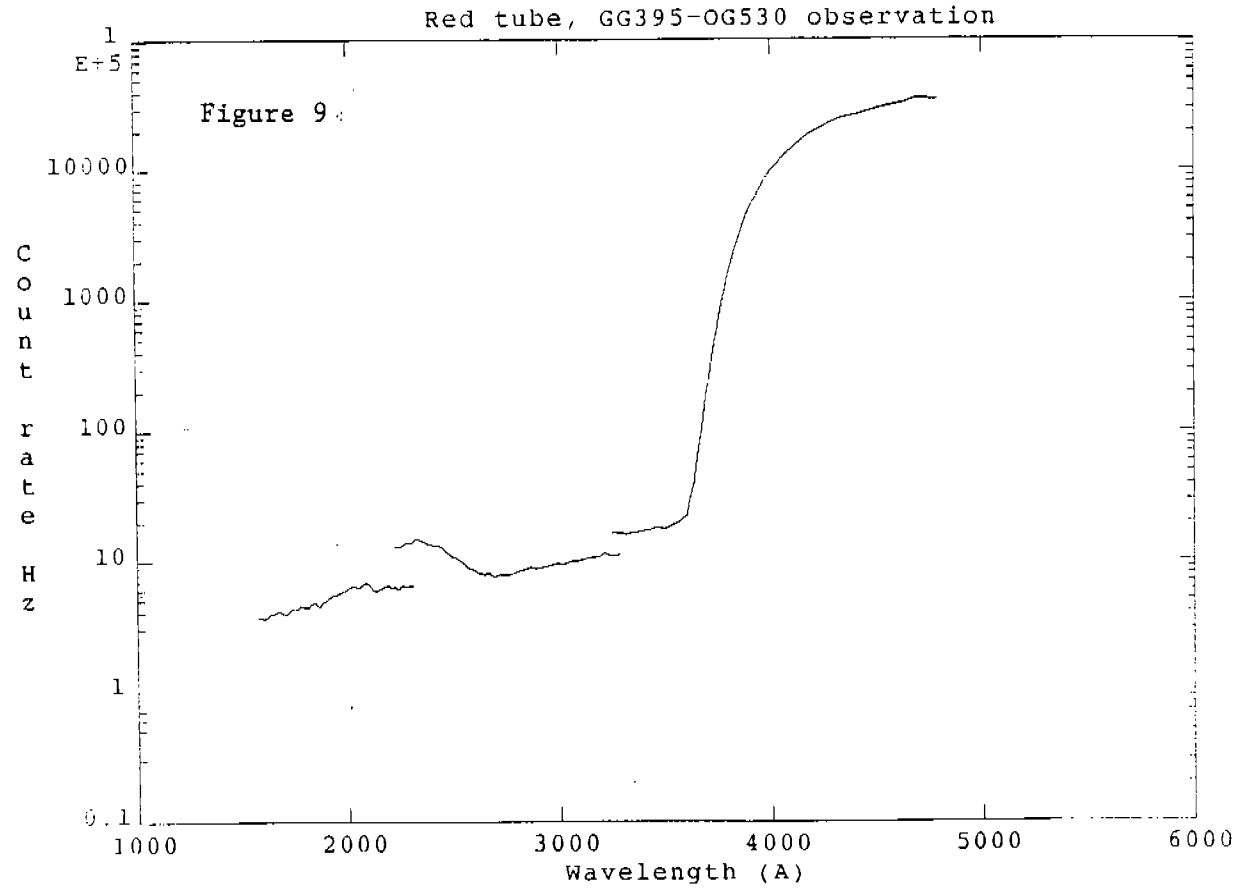

Blue tube, WG295-GG395 observations
Figure 4
1 E+5
10000
1000
100
10
1
0.1
Count rate Hz
1000
2000
3000
4000
5000
6000
Wavelength (A)

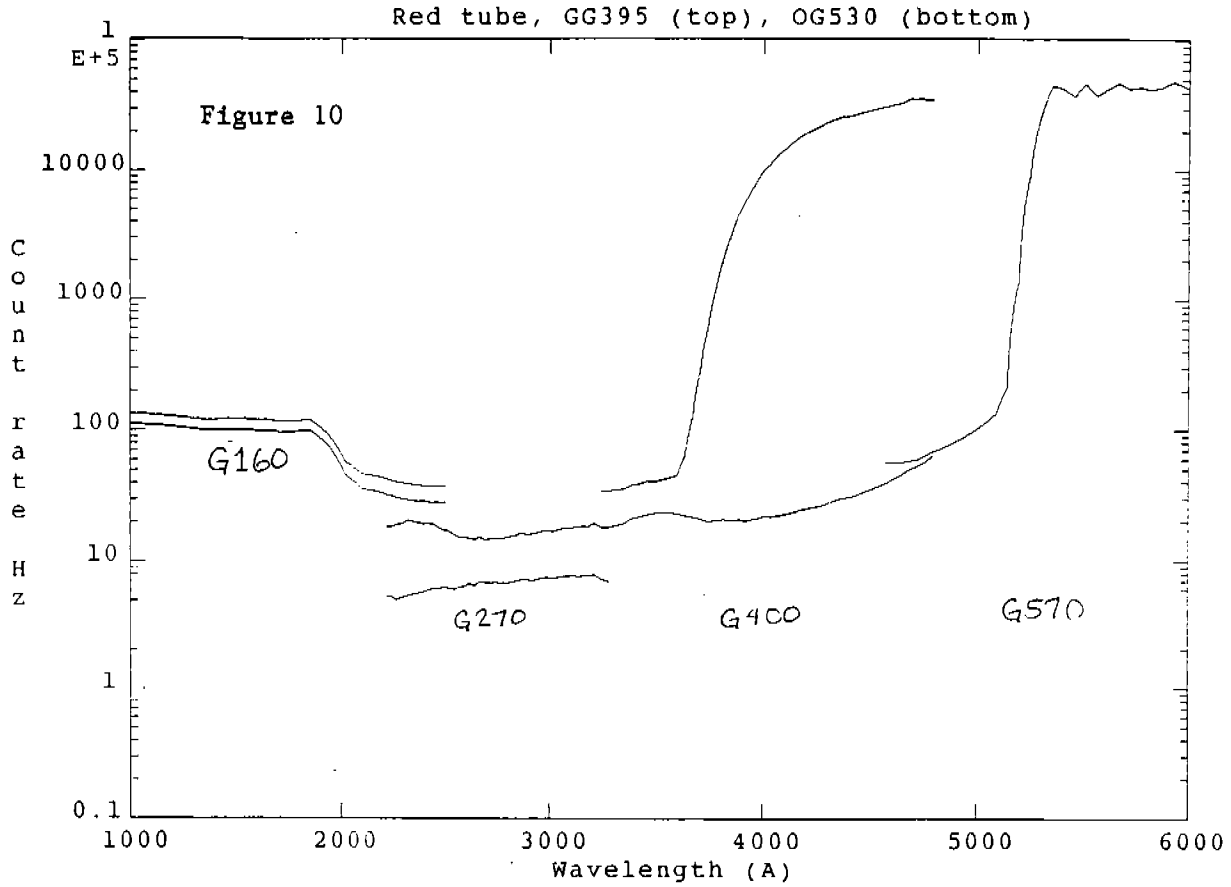

Blue tube, GG395
Figure 5
1 E+5
10000
1000
100
10
1
0.1
Count rate Hz
G130
G190
G270
G400
1000
2000
3000
4000
5000
6000
Wavelength (A)

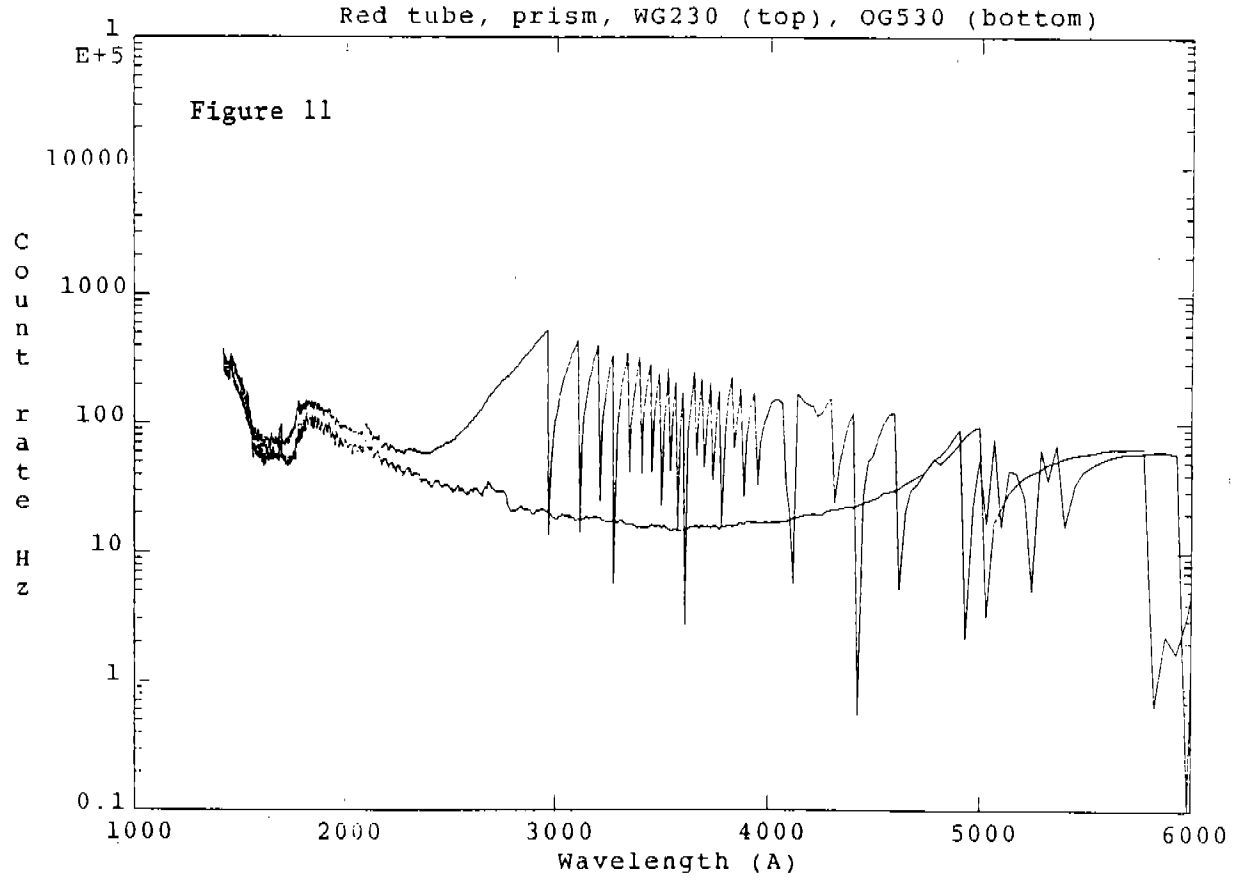

Blue tube, WG295 (top), GG395 (bottom)
Figure 6
Count rate Hz
1 E+5
10000
1000
100
10
1
0.1
G160
G270
G400
1000
2000
3000
4000
5000
6000
Wavelength (A)


Blue tube, prism, WG230, GG395
Figure 7
Count rate Hz
1 E+5
10000
1000
100
10
1
0.1
1000
2000
3000
4000
5000
6000
Wavelength (A)


Red tube, GG395 (top), OG530 (bottom)
Figure 8
Count rate Hz
1 E+5
10000
1000
100
10
1
0.1
G190
G270
G400
G570
1000
2000
3000
4000
5000
6000
Wavelength (A)


Red tube, GG395-OG530 observation
Figure 9
Count rate Hz
1 E+5
10000
1000
100
10
1
0.1
1000
2000
3000
4000
5000
6000
Wavelength (A)


Red tube, GG395 (top), OG530 (bottom)
Figure 10
Count rate Hz
1 E+5
10000
1000
100
10
1
0.1
G160
G270
G400
G570
1000
2000
3000
4000
5000
6000
Wavelength (A)


Red tube, prism, WG230 (top), OG530 (bottom)
Figure 11
Count rate Hz
1 E+5
10000
1000
100
10
1
0.1
1000
2000
3000
4000
5000
6000
Wavelength (A)