INTERNAL FOS Pt–Cr–Ne CALIBRATION LAMPS
Performance in the Far UV

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Abstract

Adequate wavelength calibrations are obtainable for H13 from 15 and 14 lines from the normal and cross-strapped lamps, respectively, with a RMS difference of 0.065Å. However, the five lines between 1169 and 1220Å, which should be prominent in Pt–Cr–Ne lamps, cannot be identified in H13 spectra of 400s duration (100s per quarter step) from the internal lamps. The attenuation of the far UV lines is probably caused by the poor focus of these wavelengths, due to the rapidly increasing index of refraction of the MgF_2 lens of the lamps below 1500Å. The lack of short wavelength lines leads to an uncertainty in the wavelength scale that is as bad as 80 km s^{-1} at 1150Å, or about 10 times worse than the typical error at longer wavelengths.

I. *Introduction*

The FOS contains two hollow cathode Platinum–Chromium–Neon lamps for calibration purposes that cover a spectral range from 1150Å to the IR. By the use of a beam–splitter, either lamp may be used to illuminate the two Digicon detectors. Light that is reflected by the beam splitter is referred to as *normal* and light that is transmitted (and thus passed from one side of the FOS to the other) is referred to as *cross-strapped* (See Figure 1). Light reaching the detectors via normal mode is always more intense than cross–strapped light except for a narrow region around 1500Å where the two are comparable. The efficiencies of the beam splitter measured by Acton

Research Corp. are shown in Figure 2.

II. *Comparison of Internal to External Pt–Cr–Ne Lamps*

Evidence can be seen in Figure 3 that the internal lamps are not performing perfectly. The MgF_2 cutoff at 1150Å is clearly apparent in the spectrum of the external lamp, whereas in the internal lamp the intensity gradually tapers off as one approaches 1150Å. The five labeled lines shortward of 1220Å in the external spectrum are lost in the noise (scattered light) of the internal spectrum and could not be used for wavelength calibration (Sirk and Bohlin Jan–1985). The two depicted spectra were smoothed over 30 diodes ($\approx$30Å), and the mean scattered light shortward of 1150Å was subtracted from each spectrum before producing the ratio of internal to external lamp intensity shown in Figure 4. The expected variation in intensity of the normal lamp, as a function of wavelength, due to the beam splitter, is shown as the dashed curve, which is normalized at 1500Å.

III. *Comparison of Normal to Cross-Strapped Lamps*

Figure 5 shows two H13 spectra taken with the normal and cross–strapped lamps. The individual features are nearly identical. All 15 lines used for the normal wavelength calibration are easily identified in both plots. The ratio of cross–strapped to normal intensity is determined by first smoothing the two spectra over 30 diodes, subtracting the mean scattered light shortward of 1150Å, and then dividing one by the other. This ratio is shown as Figure 6. The relative intensity of the cross–strapped lamp varies from ≈ 0.2 to ≈ 1 of that of the normal lamp over the spectral range of H13 (1150 to 1608Å). The dashed line shows the expected difference between the two lamps due to the beam splitter, as normalized at 1500Å. The agreement is good below 1600Å indicating that the difference in the observed fluxes between the lamps, in the far UV, is attributable to the optical properties of the beam splitter.

IV. *Adequacy of Internal Pt–Cr–Ne Lamps for Wavelength Calibration*

Grating H13 is calibrated using the internal lamp in the normal mode. Failure of this lamp during flight would necessitate the use of the fainter cross–strapped lamp for future calibrations. The usefulness of this lamp is verified by performing a wavelength calibration and comparing it to the normal lamp calibration. Spectral shifts, due to filter–grating wheel play, are removed before performing calibrations by subtracting the mean offset between the normal and cross–strapped spectra (in this case, −0.67 pixel). Of the 15 lines used for the normal calibration, 14 were used for the cross–strapped calibration. Line 1309 was rejected due to a large residual. The maximum difference is +0.25Å (at pixel 60, the 1150Å MgF_2 cutoff), while the RMS difference between the two wavelength dispersion solutions is 0.065Å.

If the lamps should fade in intensity in the far UV (as opposed to failing completely), wavelength calibrations will be affected. For example, if five more lines at the shortest wavelengths disappear (1238 thru 1327Å in Fig. 3) a cubic fit to the ten remaining lines results in an unacceptably large error of −8.5Å at 1150Å. A linear fit to these same lines results in a significant error of −0.91Å at 1150Å. The difference of these three calibrations with respect to the normal internal calibration are summarized in Figure 7.

Figure 8 shows two additional internal Pt–Cr–Ne spectra for which calibrations were performed. The RMS difference between the normal calibration of July 13 and that of July 19 is 0.043Å, with a maximum difference of +0.16Å at the 1150Å cut-off. The RMS difference between the normal July 13 calibration and the cross–strapped calibration of July 19 is 0.082Å, with a maximum difference of +0.28Å at 1150Å.

Figure 9 shows two more normal internal Pt–Cr–Ne spectra where calibrations could not be performed due to insufficient counting statistics. The lamps are very repeatable in a qualitative sense, and no significant differences are apparent with respect to the previous spectra.

V. *Conclusions*

Both the normal and cross-strapped lamp modes are marginally adequate for wavelength calibration for the H13 grating, blue tube. The RMS difference between the calibrations from the two lamps, in the useful range of H13 (pixel 60 thru 516, 1150 to 1608Å), is 0.065Å with a maximum difference of +0.25Å for July 13, and is 0.082Å with a maximum difference of +0.28Å for July 19, at 1150Å. These maximum differences are 10 times greater than either of the individual RMS residuals of the normal and cross-strapped calibrations. The five shortest lines that are visible in the external spectrum, but absent in the internal one, would reduce the uncertainty in the wavelength calibration in that region. The scientific implications are that FOS velocity measurments will be reduced from a typical accuracy of 8 km s^{-1} to 80 km s^{-1} at 1150Å. Any degradation of the lamps from their present state would affect the accuracies in the important region around Lyman–alpha at 1216Å.

The lamps are consistent with respect to individual line features; the cross-strapped lamp is fainter, as expected from the efficiencies of the beam splitter. Both internal lamps show a rapid drop in intensity below 1500Å relative to the external lamp. A reason for the weakness of the far UV from the lamps may be that the internal lamps utilize a MgF_2 lens, whereas the external lamp uses a plane MgF_2 window. The index of refraction of MgF_2 increases rapidly as one approaches 1150Å, ranging from $\approx$ 1.5 at 1380Å to $\approx$ 1.9 at 1150Å (William *et al.* 1967, *J. Appl. Phys.* **38**, 1701). Since the MgF_2 lens has an optimal focus longward of 1500Å, the shortest wavelengths will not be focused on the FOS entrance apertures. The focal distance from the MgF_2 lens to the entrance apertures on the FOS is 275mm. In the case of the IUE, which utilizes an identical lens, the optimum focus is at 1350Å for the 125mm focal distance (Mount, G.H. *et al.* 1967, *Appl. Opt.*, **16**, 591). Future users of Pt–Cr–Ne lamps with MgF_2 lenses may wish to optimize the focus in the 1200 to 1400Å region to ensure adequate UV flux down to the 1150Å cutoff.

Figure Captions

Figure 1. Calibration lamp/beam-splitter configuration. Normal is reflected; cross-strapped is transmitted. Note the MgF_2 lens on the lamps. (Not to scale).

Figure 2. Absolute reflectance (normal) and transmittance (cross-strapped) of the beam splitter as measured by Acton Research Corp. on 8/20/1980.

Figure 3. Internal and external Pt–Cr–Ne spectra for H13, aperture A4, blue tube. The external lamp is distinctly brighter in the far UV relative to 1500Å and has five additional identifiable lines. Note the distinct MgF_2 cutoff at 1150Å in the external plot.

Figure 4. Relative ratio of intensity of the internal lamp to the external lamp. The spectra from Fig. 3 were smoothed over 30 diodes (about 30Å) and the mean scattered light shortward of 1150Å was subtracted before the ratio was determined. The dashed line represents the expected variation of the normal lamp due to the beam splitter. Both curves are normalized at 1500Å.

Figure 5. Comparison spectra of normal and cross–strapped calibration lamps. The line features are nearly identical but the average intensity is attenuated more strongly for the shorter wavelengths of the cross-strapped lamp.

Figure 6. Ratio of the cross–strapped to normal lamp for the H13 region determined in the same manner as that of Fig. 4. The dashed line represents the expected variation between the two lamps due to the beam splitter.

Figure 7. Differences between the normal calibration and the:
a) cross–strapped, 14 lines; b) cubic, 10 lines; and c) linear, 10 lines.

Figure 8. Additional normal and cross–strapped spectra used for wavelength calibration comparisons.

Figure 9. Two normal internal spectra used for qualitatively verifying lamp repeatability.

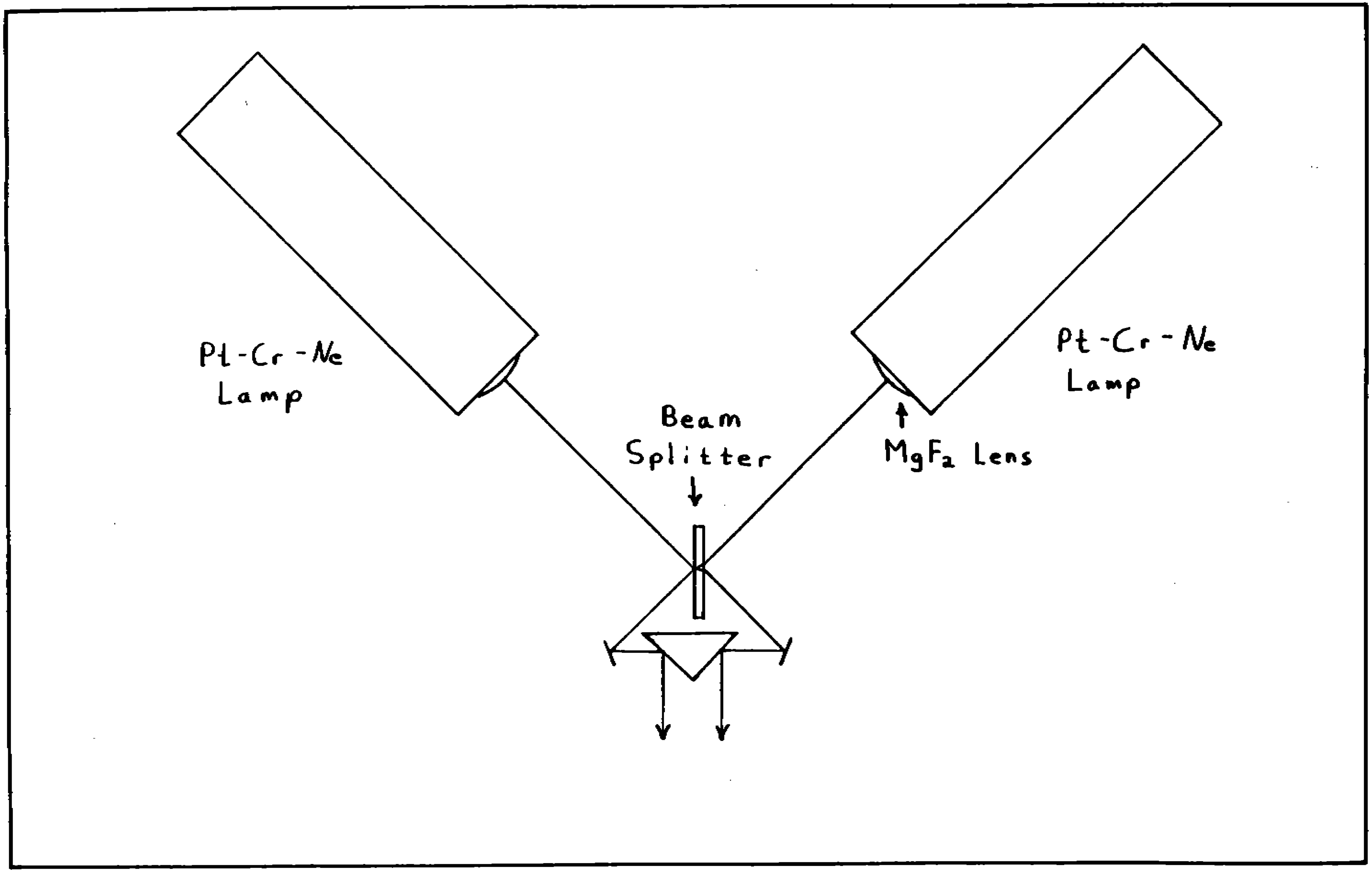


Figure 1.

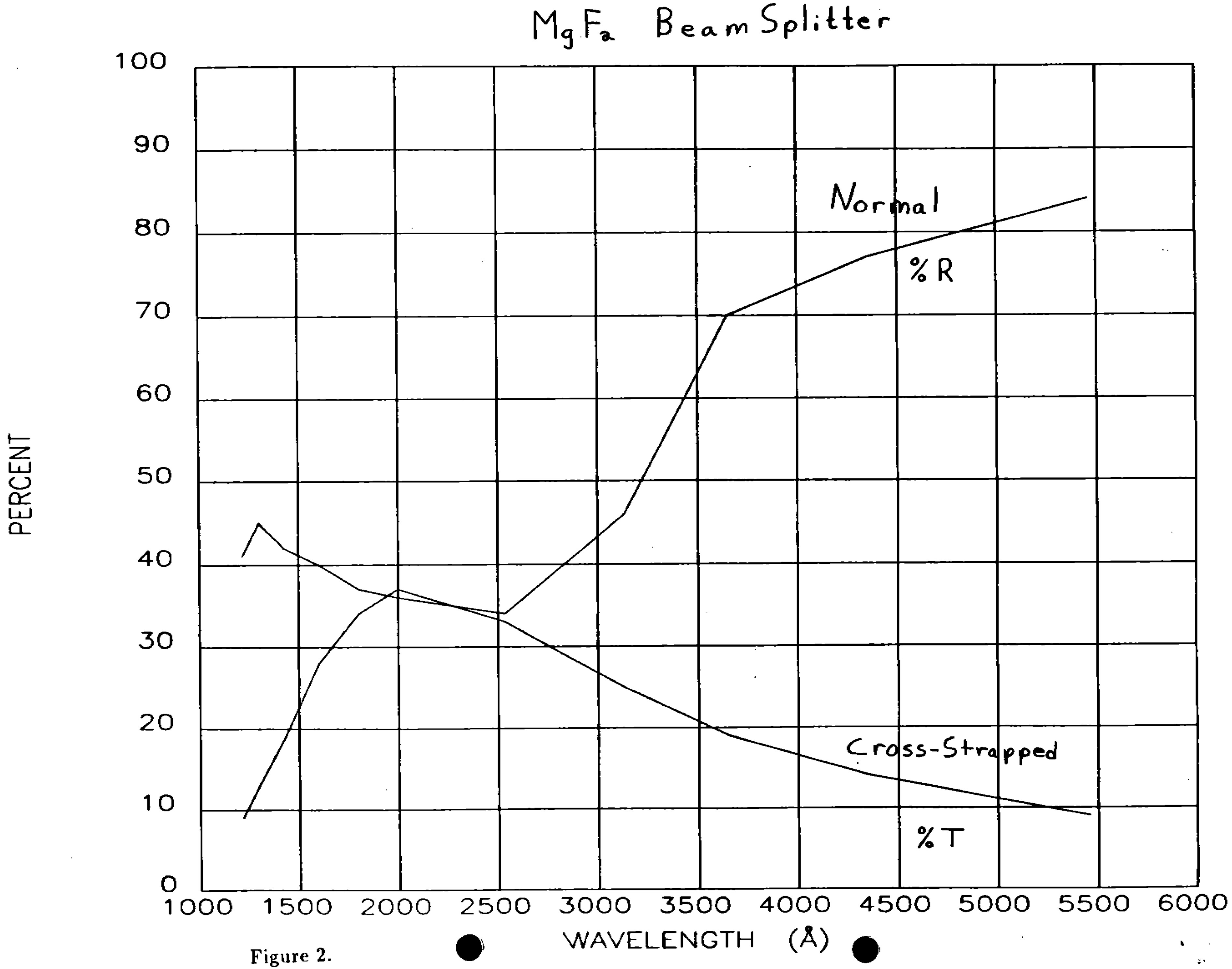

MgF2 Beam Splitter
100
90
80
70
60
50
40
30
20
10
0
PERCENT
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
WAVELENGTH (Å)
Normal
%R
Cross-Strapped
%T

Figure 2.

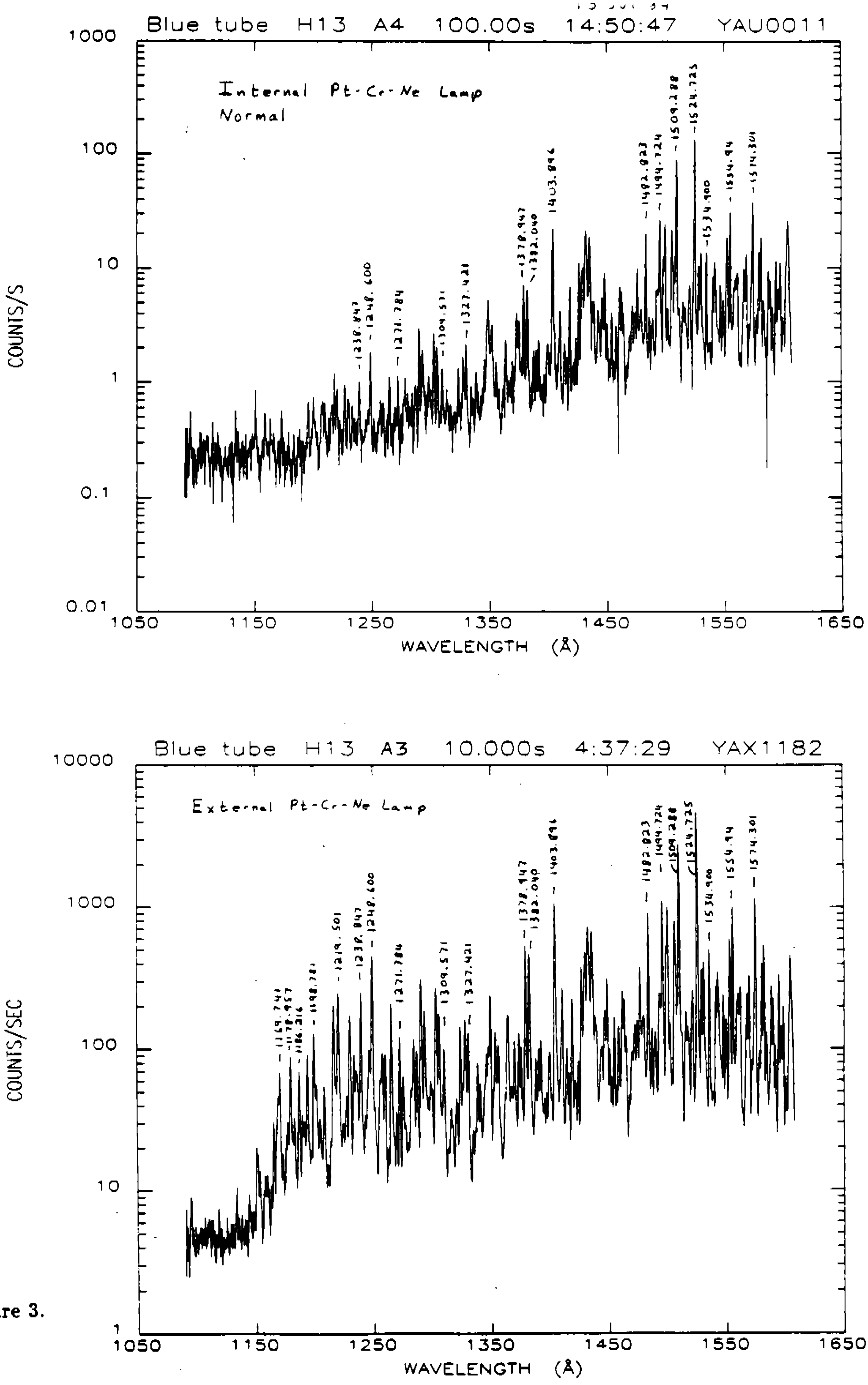

Blue tube H13 A4 100.00s 14:50:47 YAU0011
Internal Pt-Cr-Ne Lamp
Normal
COUNTS/S
WAVELENGTH (Å)
1403.896
1509.288
1524.725
1482.823
1494.724
1534.900
1554.94
1574.301
1378.947
1382.040
1238.847
1248.600
1271.784
1309.571
1327.421
Blue tube H13 A3 10.000s 4:37:29 YAX1182
External Pt-Cr-Ne Lamp
COUNTS/SEC
WAVELENGTH (Å)

Figure 3.

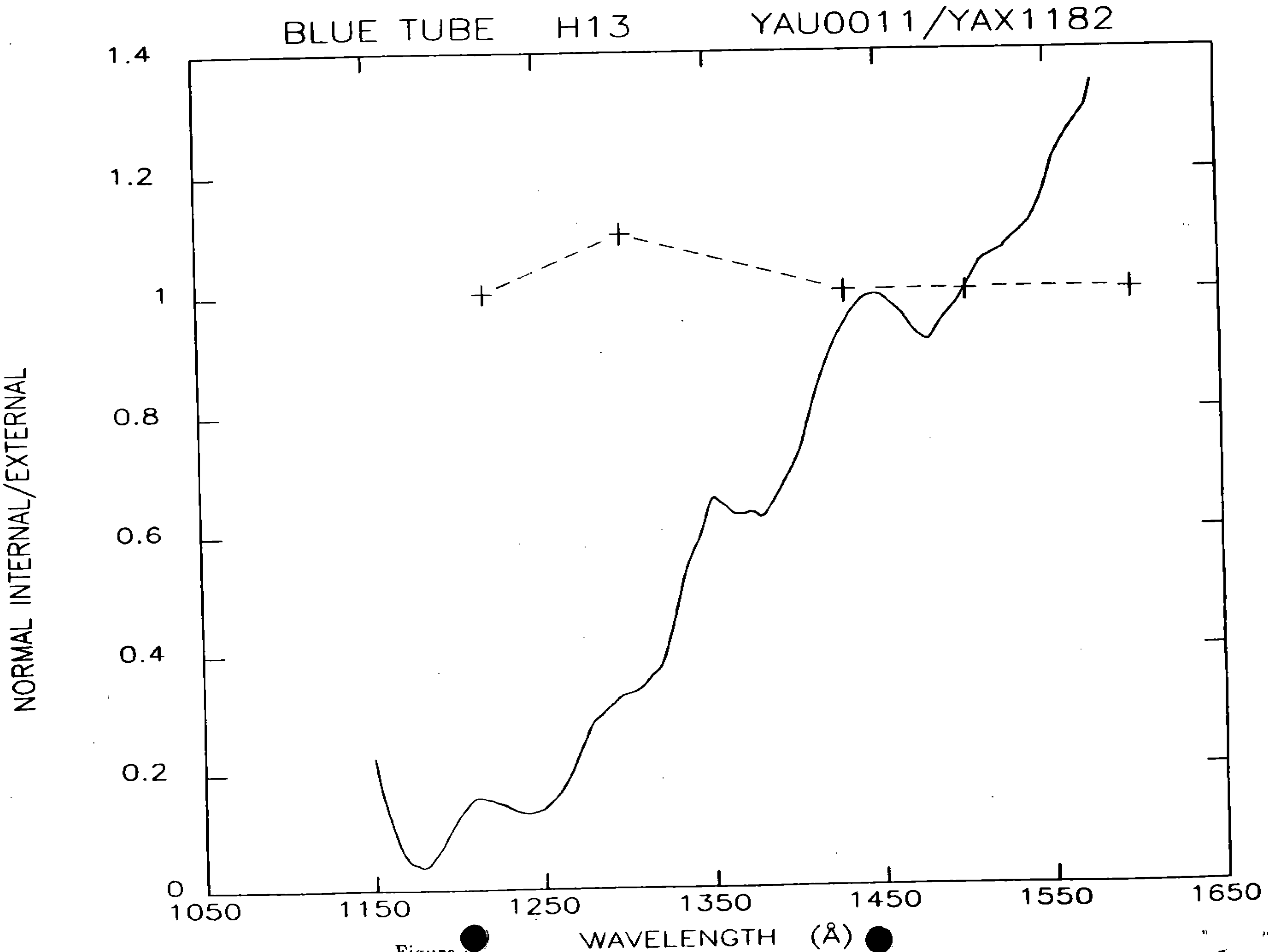
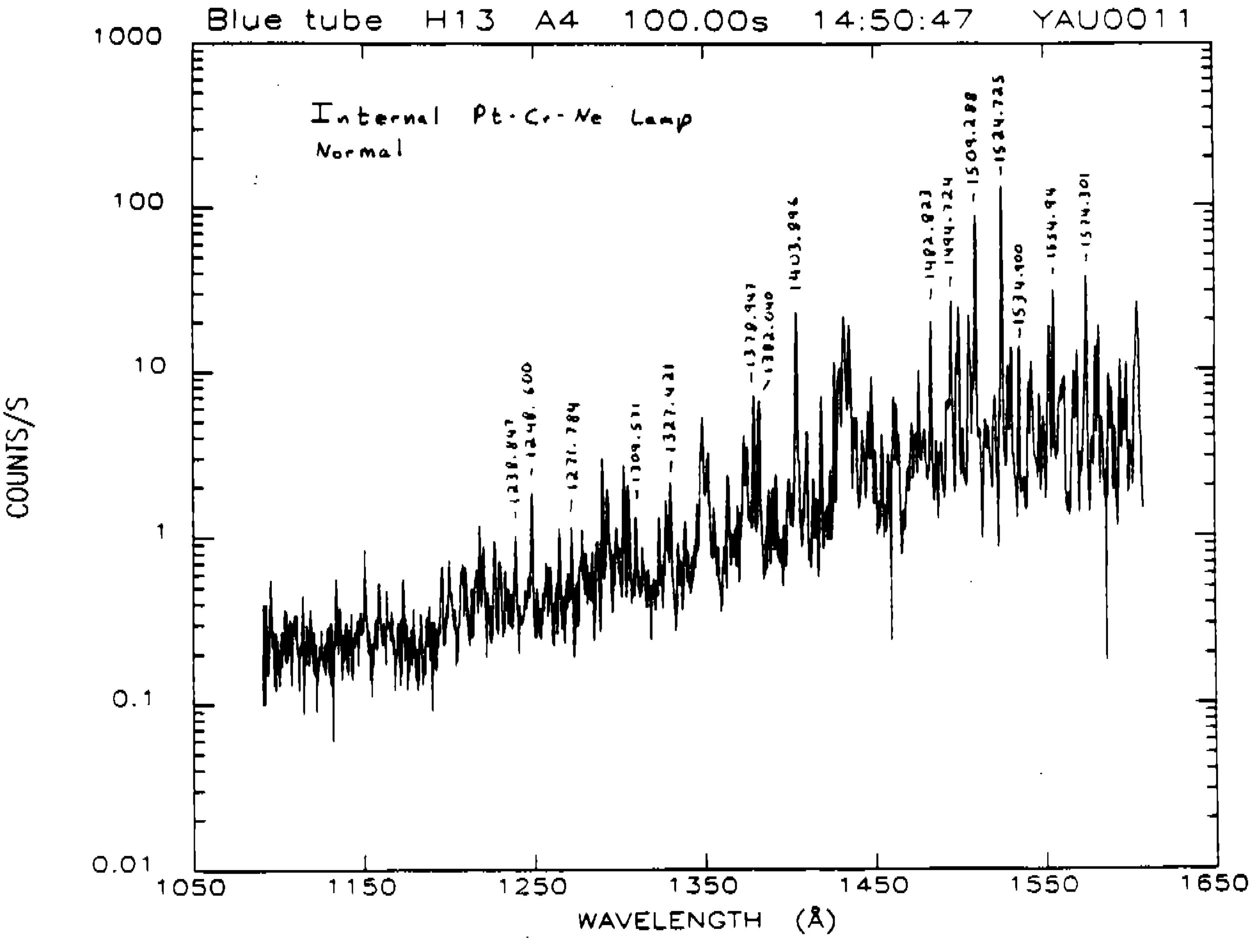

BLUE TUBE H13 YAU0011/YAX1182
NORMAL INTERNAL/EXTERNAL
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1050
1150
1250
1350
1450
1550
1650
WAVELENGTH (Å)

Figure 4.


Blue tube H13 A4 100.00s 14:50:47 YAU0011
Internal Pt-Cr-Ne Lamp
Normal
COUNTS/S
WAVELENGTH (Å)
1238.847
1248.600
1271.784
1309.571
1327.421
1378.947
1382.040
1403.896
1482.823
1494.724
1509.288
1524.725
1534.900
1554.94
1574.301

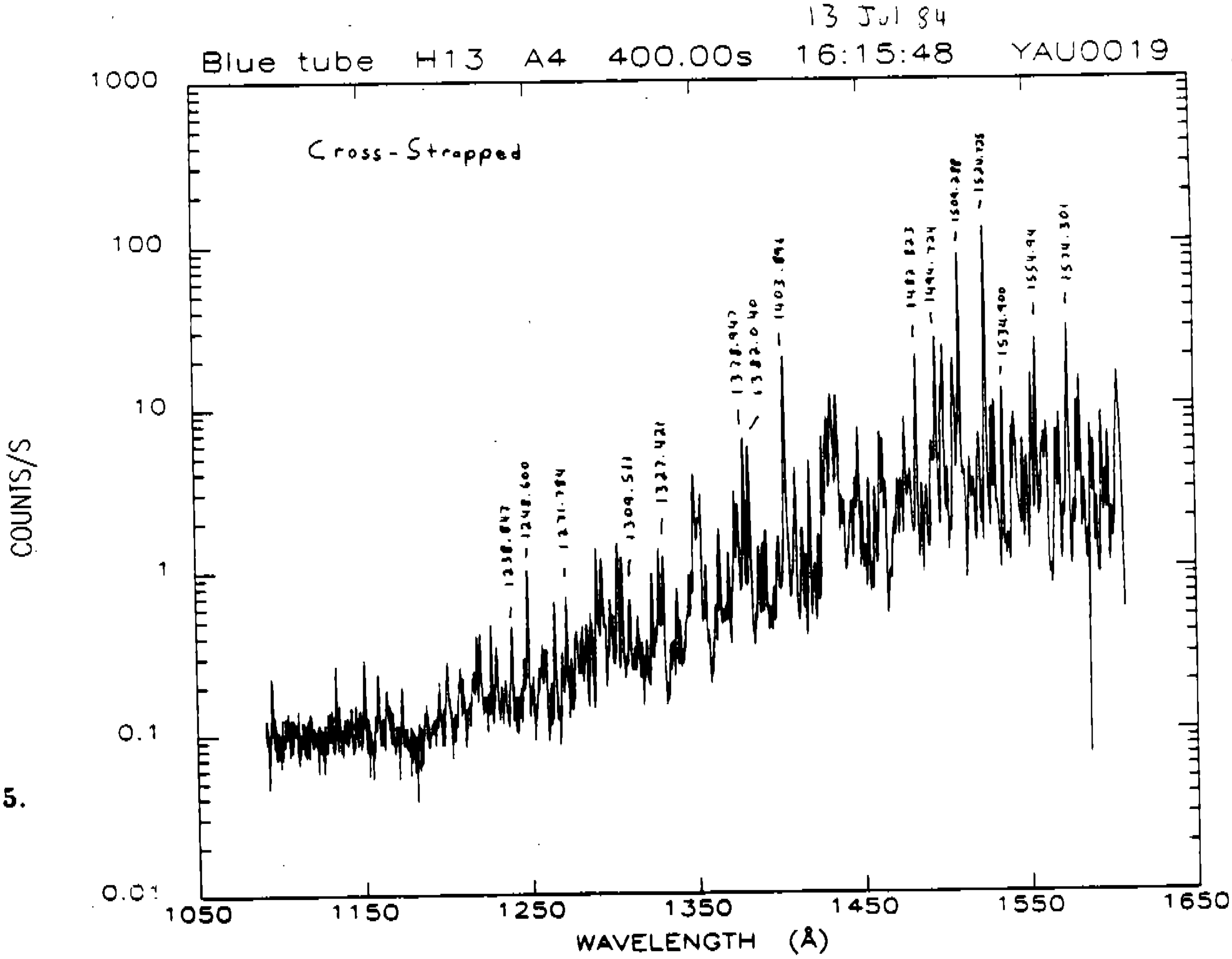

13 Jul 84
Blue tube H13 A4 400.00s 16:15:48 YAU0019
Cross-Strapped
COUNTS/S
WAVELENGTH (Å)

Figure 5.

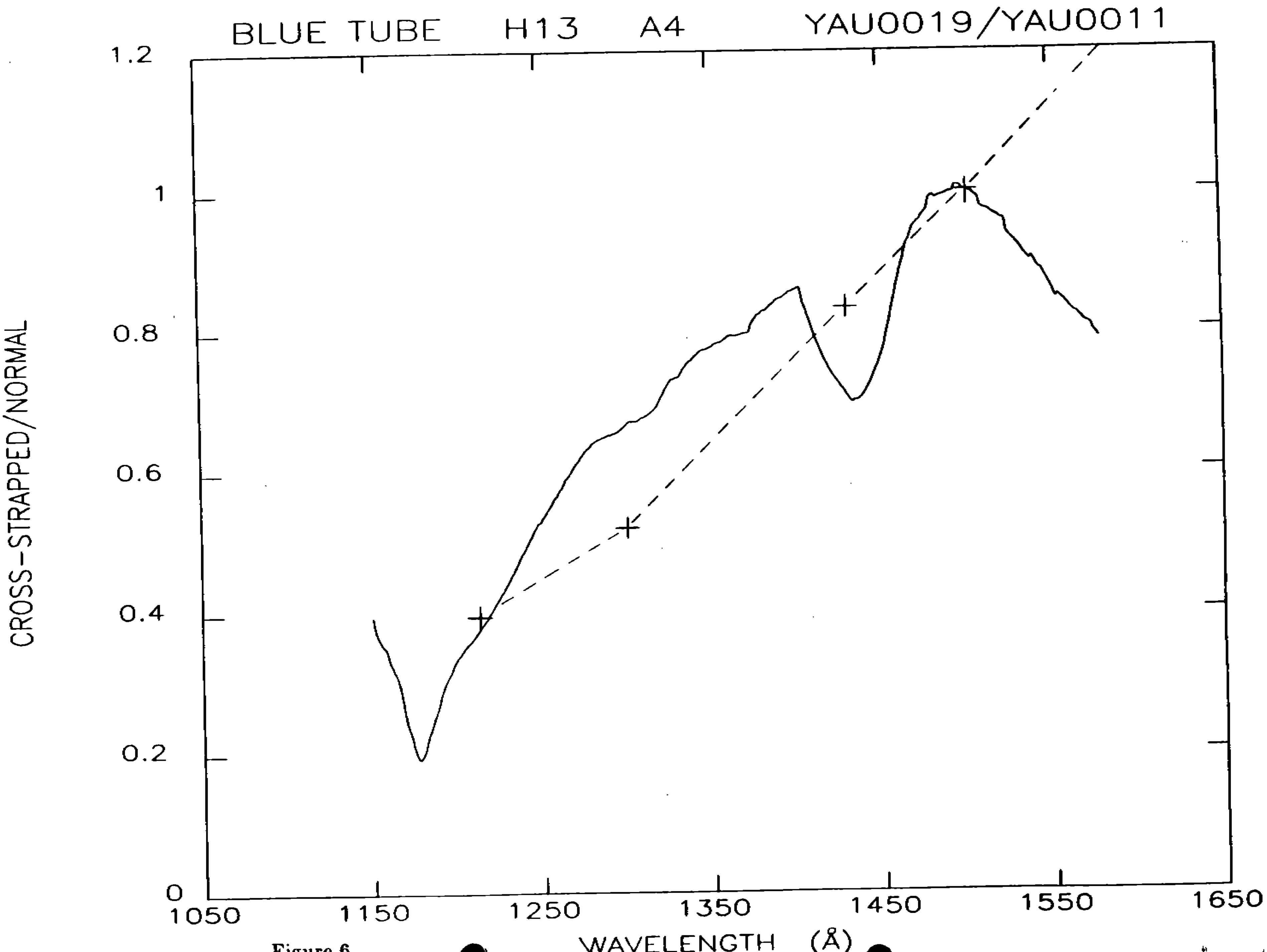

BLUE TUBE H13 A4 YAU0019/YAU0011
CROSS-STRAPPED/NORMAL
1.2
1
0.8
0.6
0.4
0.2
0
1050
1150
1250
1350
1450
1550
1650
WAVELENGTH (Å)

Figure 6.

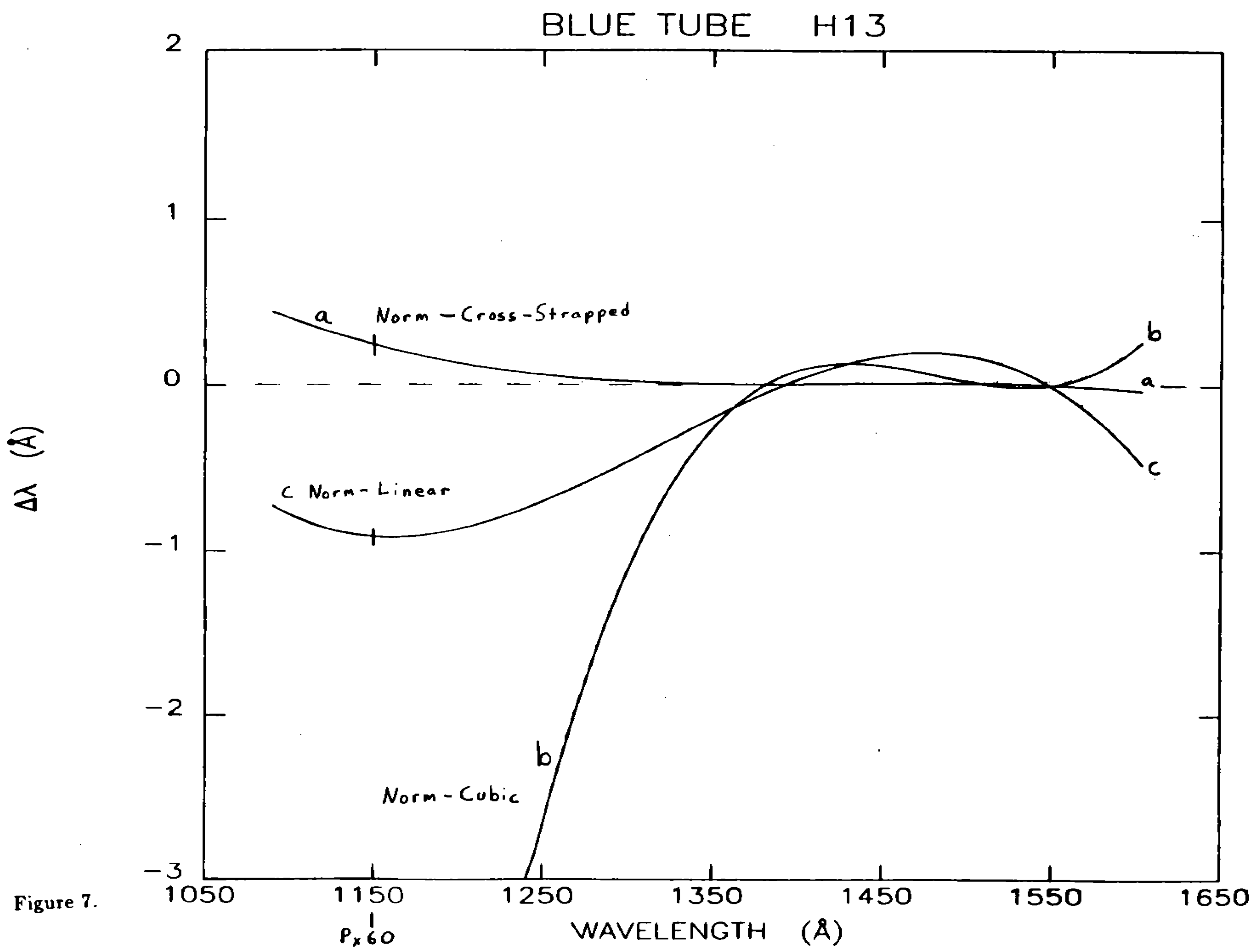

BLUE TUBE H13
2
1
0
−1
−2
−3
1050
1150
1250
1350
1450
1550
1650
WAVELENGTH (Å)
Δλ (Å)
Px60
a Norm – Cross-Strapped
c Norm-Linear
Norm-Cubic
a
b
c

Figure 7.

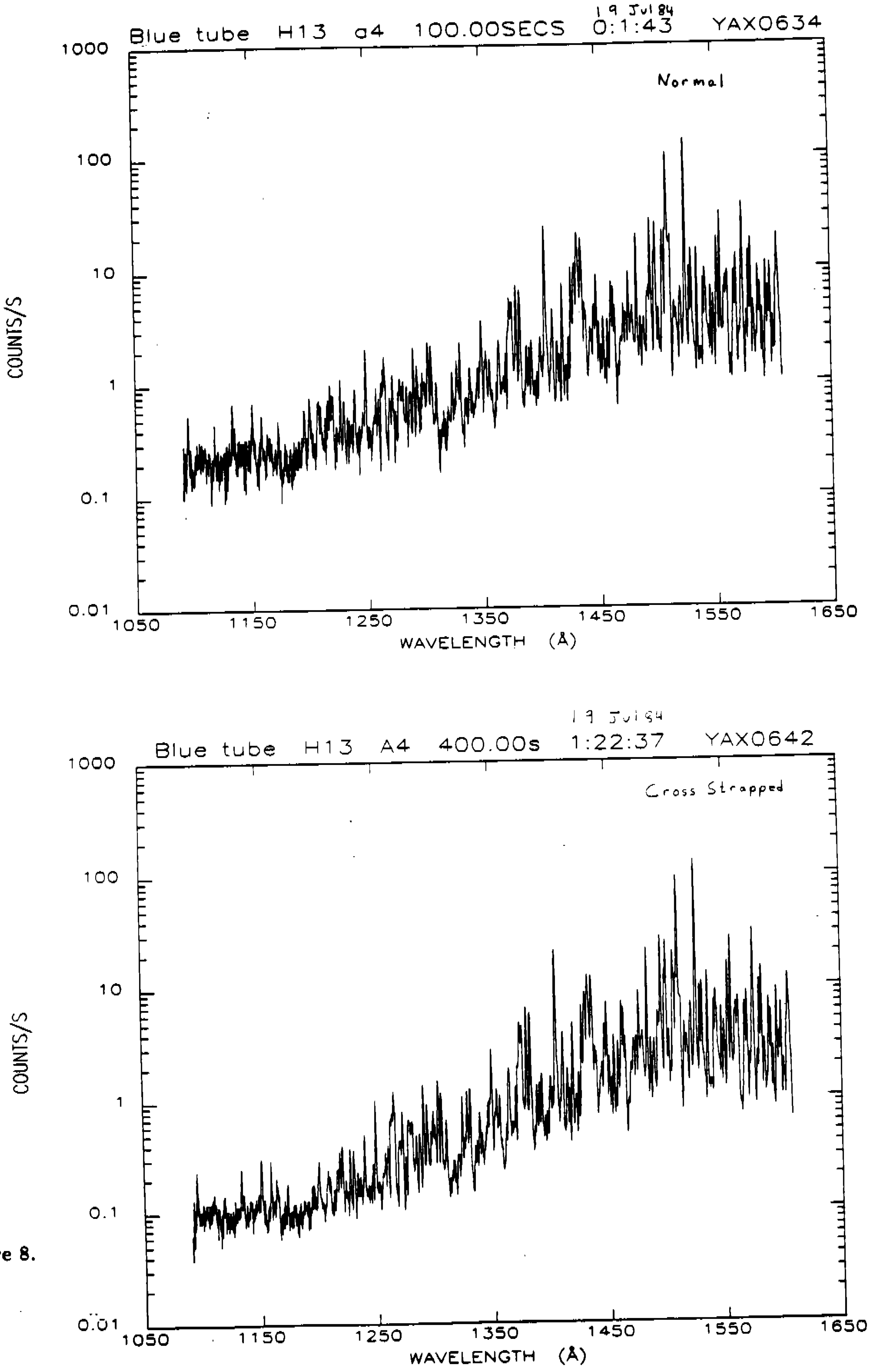
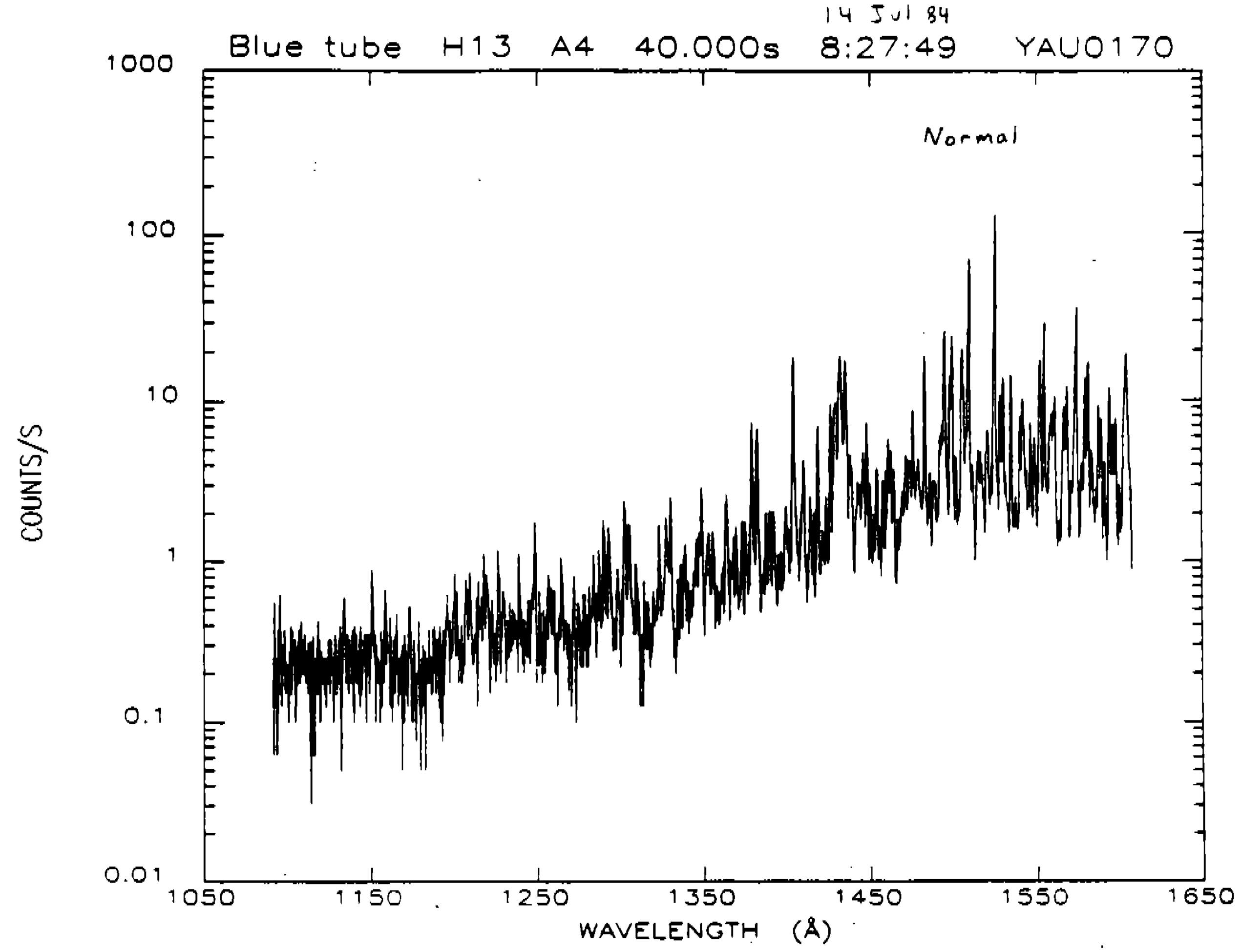

19 Jul 84
Blue tube H13 a4 100.00SECS 0:1:43 YAX0634
Normal
1000
100
10
1
0.1
0.01
COUNTS/S
1050
1150
1250
1350
1450
1550
1650
WAVELENGTH (Å)
19 Jul 84
Blue tube H13 A4 400.00s 1:22:37 YAX0642
Cross Strapped
1000
100
10
1
0.1
0.01
COUNTS/S
1050
1150
1250
1350
1450
1550
1650
WAVELENGTH (Å)

Figure 8.


14 Jul 84
Blue tube H13 A4 40.000s 8:27:49 YAU0170
Normal
COUNTS/S
1000
100
10
1
0.1
0.01
1050
1150
1250
1350
1450
1550
1650
WAVELENGTH (Å)

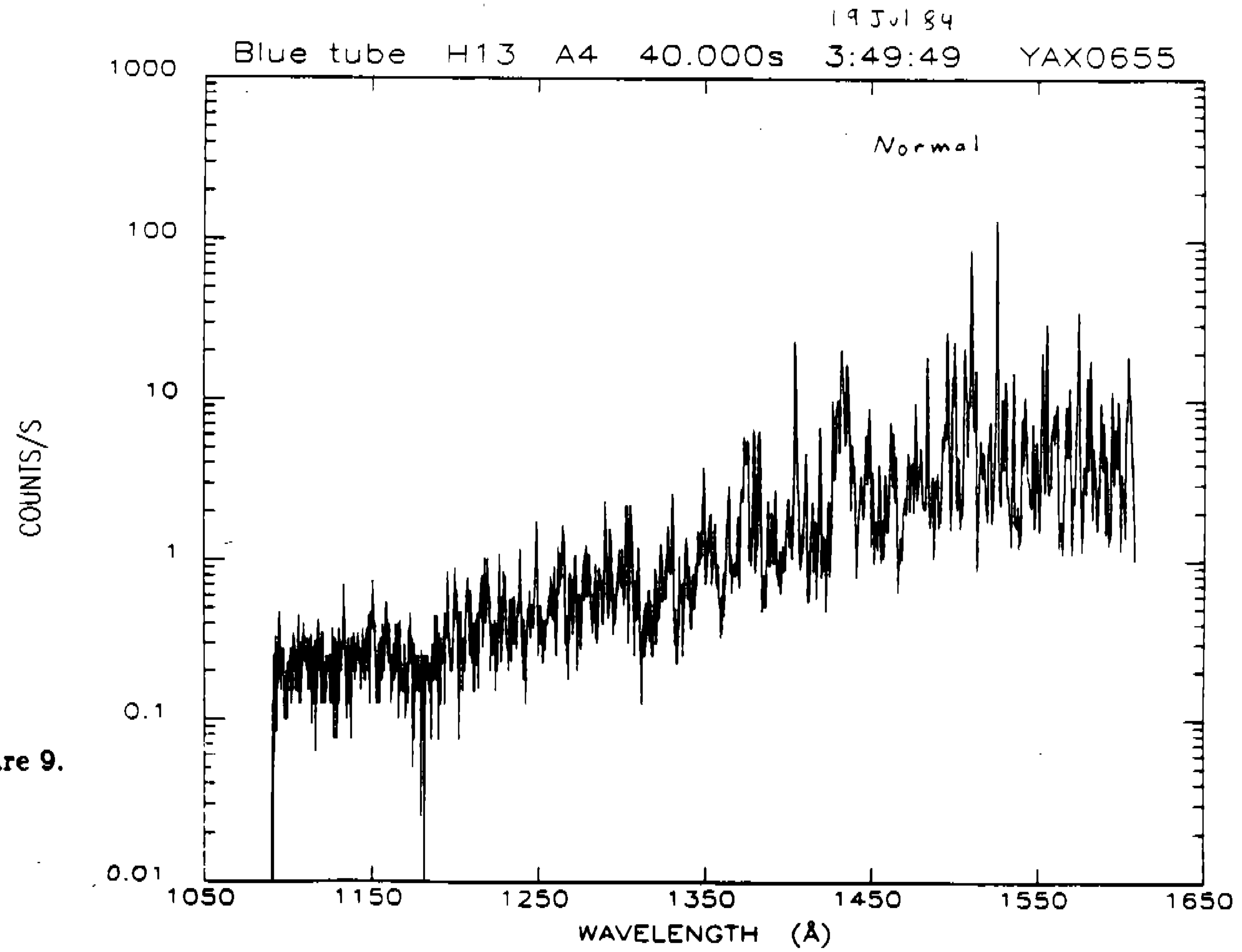

19 Jul 84
Blue tube H13 A4 40.000s 3:49:49 YAX0655
Normal
COUNTS/S
1000
100
10
1
0.1
0.01
1050
1150
1250
1350
1450
1550
1650
WAVELENGTH (Å)

Figure 9.