CHAPTER SEVEN: The Objective Grating Spectrometer (OGS)

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7.0 Introduction

The objective grating spectrometer consists of two transmission gratings, either of which was placed in the X-ray optical path at the exit from the mirror. The HRI was used to detect the diffracted images. The gratings consisted of gold lines about 0.2 μ thick and 0.5 μ wide, separated by open spaces of the same width. These two sets of gratings had 500 and 1000 lines/mm respectively. The 1000 line/mm gratings were coated with ~2.5 μm parylene to give mechanical strength with consequent reduction in sensitivity at low energies.

Characteristics of Gratings

	500 l/mm	1000 l/mm
Dispersion (Å/arc sec on HRI)	0.1278	0.0625
Range, HRI center on axis, 1st order	3-101 Å	3-45 Å
Range, HRI edge on axis, 1st order	3-202 Å	3-99 Å

Only 53 pointings were accomplished using the OGS. The 1000 line/mm gratings were used for observing bright, hard sources, such as galactic bulge sources, and the 500 line/mm gratings to observe the soft sources, such as white dwarfs. Only the brightest sources produced useful spectra. The analysis programs were not written for the general user so advice from a previous user is probably necessary.

All OGS data were taken with HRI #3. The calibration was done with HRI #1 and is described in Applied Optics, 21, 2021 (1982), which also shows the instrument response to several monoenergetic lines.

7.1 OGS DATA ANALYSIS

This section outlines the data analysis programs available for OGS spectra. The program recipes given are meant to be useful to occasional users of OGS data. A more detailed writeup is available from Fred Seward and will be necessary for first-time users

1 Load data on M600 computer. Only the .IMG and .MPT files are necessary. OGS data are processed differently from normal HRI images in that:

   a) The instrument roll is not removed and the dispersed spectrum appears as a horizontal line across the image. This is not exact. The two HRI stops cause opposite tilts of a few degrees.

   b) No computer search is made for sources in the field.

2 Visual inspection of field using TV.

   a) Find center of zero order image using eye and program CENTROID;

   b) Is source a point source or extended?

   c) Are there any field sources accidently appearing in the diffracted data?

3 Extract spectral data using a mask. This is done with the program GZOOM, which creates a one-dimensional array (4096 x 1). This is the raw spectrum to be processed by following programs. The mask width is selected for optimum signal to noise. The good resolution of a narrow mask is usually somewhat sacrificed to collect more counts. The recommended mask width is 80 pixels for most hard sources.

(3') If several spectra are to be merged, the program OPARRAY will add these one-dimensional arrays. The user must first make sure that the zero order position is the same in all arrays to be added.

4 Using the program QLPLT, plot the raw data to verify that the zero order is at coordinate 2048 and to determine data limits set by edges of the HRI. Sometimes real spectral features can be seen in this plot as well as anomalies caused by imperfect gap removal.

5 Determine the background to be subtracted. This has two components: a constant background which usually is within a factor of 2 of 1.5×10^{-6} counts/s. arcsec^2, and a component due to scattering of zero order photons from the gratings which is approximated by a Gaussian function centered at the zero order. Parameters specifying these components are generated by fitting models to the image brightness above and below the zero order image.

   The program FITBACKGROUND.HGET is used to make plots of surface brightness in four quadrants centered on the zero order image. These are used to determine the radial limits of the scattering-wing background and the constant background. These limits are input to the program FITBACKGROUND, which produces plots showing background model fits to the two background quadrants and a listing of model parameters. These parameters are entered into the next program, PREOGB.

6 Edit the parameter file POOGS.PF so it contains correct value for:

a) grating constant (500 or 1000 line/mm);

b) zero order position;

c) width of zero order peak;

d) mask width;

e) left and right boundaries of data.

7 Use program PREOGB to prepare raw spectrum for next program. PREOGB does the following:

a) compresses the data a factor of 2. The output is a 2048 x 1 array;

b) calculates background for later subtraction;

c) adds left and right sides together if desired. Output files are FIT.FILE and POPR.OUT.

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Further processing can be performed on the M600 or the VAX. We first describe the VAX programs.

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8 Run CREATE.PEAK, which records the shape of the projected (masked) zero order peak. Output is PEAK.

9(PreVAX) Convert the files FIT.FILE and PEAK to ASCII for transferal to VAX using program BINASC.

10 Transfer three ASCII files to VAX:

FIT.FILE, PEAK, and POOGS.PF.

11(VAX) Name transferred ASCII files FITVAX.DAT, PEAKVAX.DAT, POOGS.PF.

12(VAX) Convert PEAKVAX.DAT and FITVAX.DAT to binary. Edit parameter file to remove ";" which are indigestible to VAX.

13(VAX) Assign system operating channels

14(VAX) Fit model spectra to data using program OGSSAO. This prompts user for input parameters in manner explained in detailed instructions. Parameters for a specified model are varied in interactive fashion to minimize χ^2. SPCTSAO will produce a file with data points and the best-fit model spectrum which can then be plotted. Data points are in the form of counts vs. wavelength and are uncorrected for detector response and efficiency.

15(VAX) The true spectrum, photons/sq. cm. sec. Angstrom vs. wavelength can be produced with TRUSPEC. Instrument efficiency and 2nd, 3rd and 4th order diffraction are removed from the spectrum and an absolute calibration applied. SPLOG produces output to be plotted.

The fitting program can also be run on the M600. Interactions are slow, however.

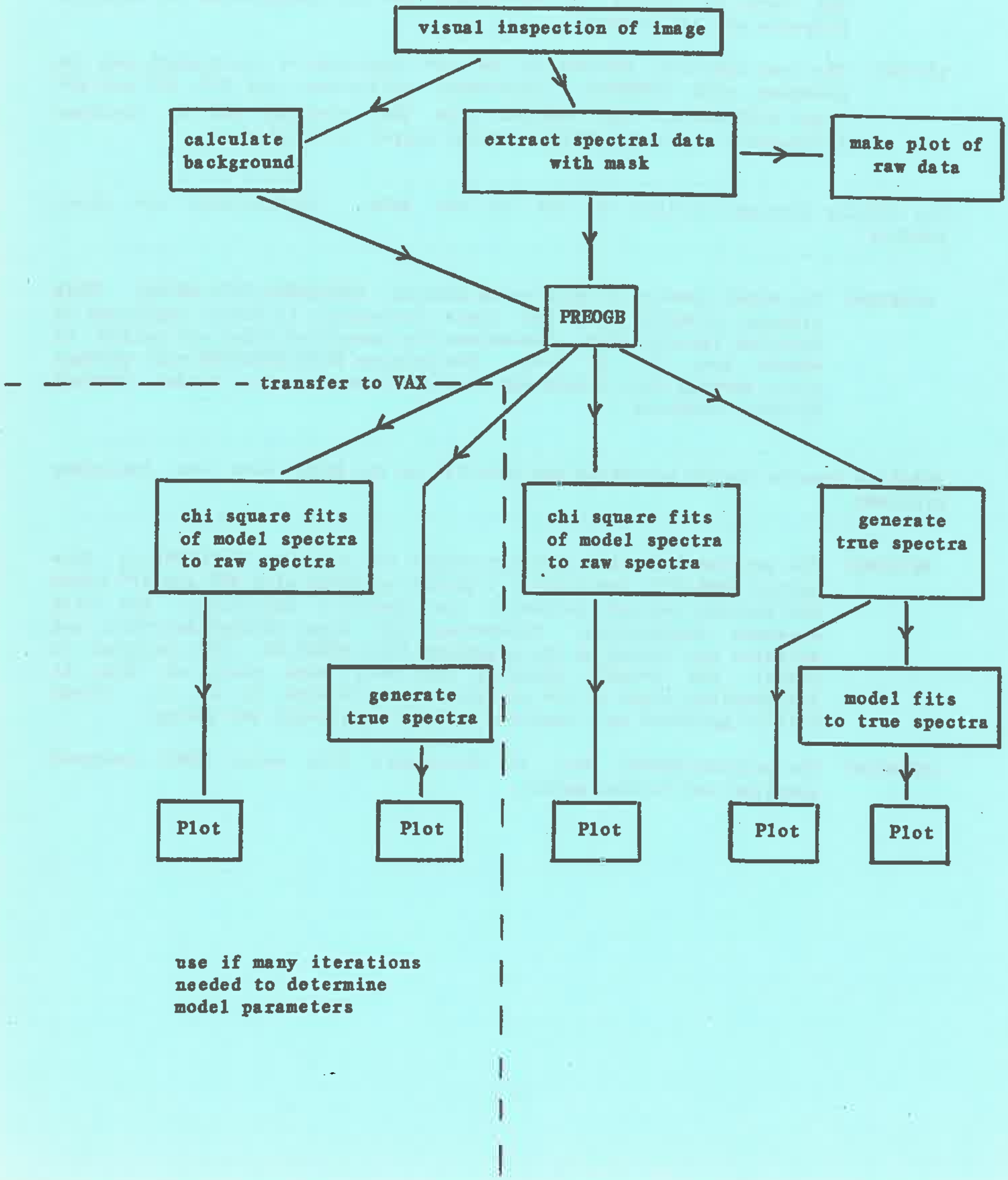
9A(M600) Fit model spectra to data using program CONTINUUM.FITS.PRIME. This program prompts user for input parameters in manner explained in detailed instructions. Parameters for specified model are varied to obtain best fit to data. The program PLOT.SPECTRUM will produce plots showing data points and best-fit model spectra folded through detector response.

Absolute spectra can be generated and then fit on the M600 with the following programs.

9B(M600) The program TOGS will take the output raw spectrum of PREOGB (a file called POPR.OUT) and produce a photon spectrum with 2nd and 3rd order diffraction removed, corrected for detector efficiency, and with absolute calibration. Parameters are input through switches, and defaults are listed in the parameter file POOGS.PF. This program is useful for trouble shooting and will make plots of data at intermediate steps of the analysis if instructed to do so. Plots will be produced as a function of both wavelength and energy.

10B(M600) The program OGSFIT will do chi-square fits using TOGS produced spectrum and various models.

F 7.1 Flow Diagram for OGS Data Analysis



7.2 Sample Computer Instructions

Be aware that your numbers and parameters will differ from those in these examples.

At this writing many OGS analysis programs are in the directories HEAOB:OGS and HEAOB:OGS:SMK. This will change in the near future, and the UGET and USEA instructions listed will either be unnecessary or different.

```
2   HIP H820.OGS
    IMAGE    Observe approximate coordinates of zero order
    CENTER 1740 2250
    ZOOM 1
    IMAGE
    BOXCUR 1740 2250
      center box on zero order
    Control D
    PROJ
    CENTROID    This gives center of zero order as 1745, 2246.
      Expand box to illustrate outline of mask to be used.
    BY

3   IMSEA/1 820
    X GZOOM H820.OGS.IMG/I G820.W80.CS/O 1745*2246/C 4096*1/D 1*80/P

4   USEA HEAOB:OGS
    QLPLT G820.W80.CS/D OGS.QPF/P 1/W 256/H

5   UGET HEAOB:OGS:SMK H824.OGS.HGET.CMDS
    RENAME H824.OGS.HGET.CMDS H820.OGS.HGET.CMDS
    ED H820.OGS.HGET.CMDS
      edit this to have correct center position and title
    USEA HEAOB:OGS:SMK
    IMSEA/1 820
    GET :Z3:IMAGES:REV1:820 +.MPT
    ELBATCH/I This is a batch job to run overnight.
    )) CREATE.BEXP H820.OGS
    )) FITBACKGROUND.HGET H820.OGS      This creates plots of average surface
                                        brightness as a function of radius in
                                        four quadrants.
    )))
    UGET HEAOB:OGS:SMK FITBACKGROUND.PF
    ED FITBACKGROUND.PF
      scattering.wing.limits  200, 550, 200, 600
      constant.term.limits    550, 700, 600, 1000
      mask.width              80
    USEA HEAOB:OGS:SMK
    FITBACKGROUND H820.OGS (produces table and plots)

6   UGET HEAOB:OGS:SMK POOGS.PF
    ED POOGS.PF
      edit for correct boundries and parameters
```

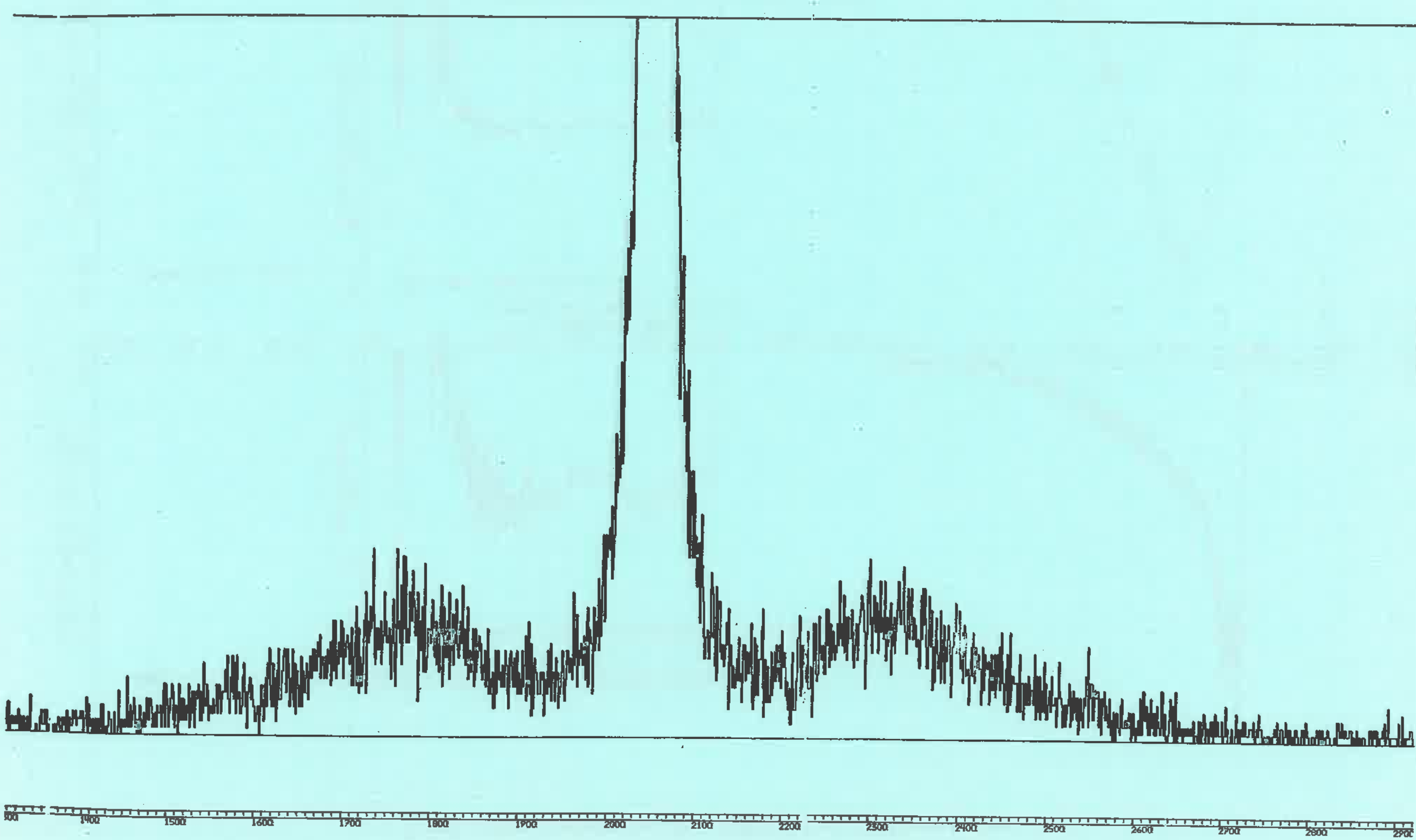
```
 7  USEA HEAOB:OGS:SMK
    PREOGB G820.W80.CS/I

    constant        .294
    peak coeff.     .357
    peak width      805.
    center          2048
    L edge           810
    R edge          3760
    to add sides       1
    zero order      2048

 8  CREATE.PEAK
    model                  2
    power law              1
    index                 -1
    NH                     2.E21
```

```
 9(pre VAX)   BINASC

10(pre VAX)   TAPWR/REC=132/BLK=1320 FITVAX  MTA0:0
              TAPWR/REC=132/BLK=1320 PEAKVAX  MTA0:1
              TAPWR/REC=132/BLK=1320 POOGS.PF  MTA0:2

10(on VAX)   OGS (username)
  (APVAX)    XRAY (password)
             CREATE/DIRECTORY [.820]
             SD .820 (puts you in subdirectory)
             SUB/QUEUE=TAPE$BATCH SYS$UTIL:READ9 /PAR=(OGS, AP1:[OGS.820]FOO.RE9)
             SUB SYS$UTIL:BRKASC /PAR=(AP1:[OGS.820]FOO.RE9,AP1:[OGS.820]FOO.OUT,132)
             SUB SYS$UTIL:SPLITFIL /PAR=(AP1:[OGS.820]FOO.OUT,AP1:[OGS.820])

             or run last two programs interactively

               SYS$UTIL:BRKASC FOO.RE9 FOO.OUT
               blocks?  132
               SYS$UTIL:SPLITFIL FOO.OUT AP1:[OGS.820]

11(on VAX)   RENAME  FILE001.DAT  FITVAX.DAT
             RENAME  FILE002.DAT  PEAKVAX.DAT
             RENAME  FILE003.DAT  POOGS.PF

12(on VAX)   RED POOGS.PF
             C;(linefeed)!(linefeed)(linefeed)
             repeat until all ;  changed to !
             W(linefeed)H(linefeed)(linefeed)

             RUN AP1:[DIL.OGS]ASCBIN

             DEL FOO.*;*
```

```
            DEL FITVAX.DAT;1
            DEL PEAKVAX.DAT;1
            DEL POOGS.PF;1

13(on VAX)  ASSIGN SYS$INPUT FOR010
            ASSIGN SYS$OUTPUT FOR011

14(on VAX)  RUN AP1:[DIL.OGS]OGSSAO
            model                         1
            xsect                         5
            bin bound                     624 1424
            0 ord bins                    954 1094
            exclude                       0
            bin size                      4
            label                         'Cyg X-1'        quotes are necessary
            lambda                        c. return
            u. lim.                       c. return
            l. lim.                       c. return
            delta                           2  3
                                          -1.
                                          -1.
            start                         c. return
            reanalyse?A. print?P.         P
            log or linear                 1
            reanalyse?A. print?P.         c. return

            PLOT PLOT.VEC;1

            PRINT WHIZOUT.DAT;1

            RUN AP1:[DIL.OGS]SPCTSAO
            label      'Cyg X-1'
            which      1
            bin bound  624   824
                       624   924
            return     0     0
            return     0
            PLOT PLOT.VEC;2

15(on VAX)  RUN AP1:[DIL.TRUSPEC]TRUSPEC
            bin boundaries    624   1424
            zero order        954   1094

            RUN AP1:[DIL.TRUSPEC]SPLOG
            label         'Cyg X-1'
            bin width     4
            bin values    624-924
            log or lin    0
            bin values    0    0

            PLOT PLOT.VEC;3
```

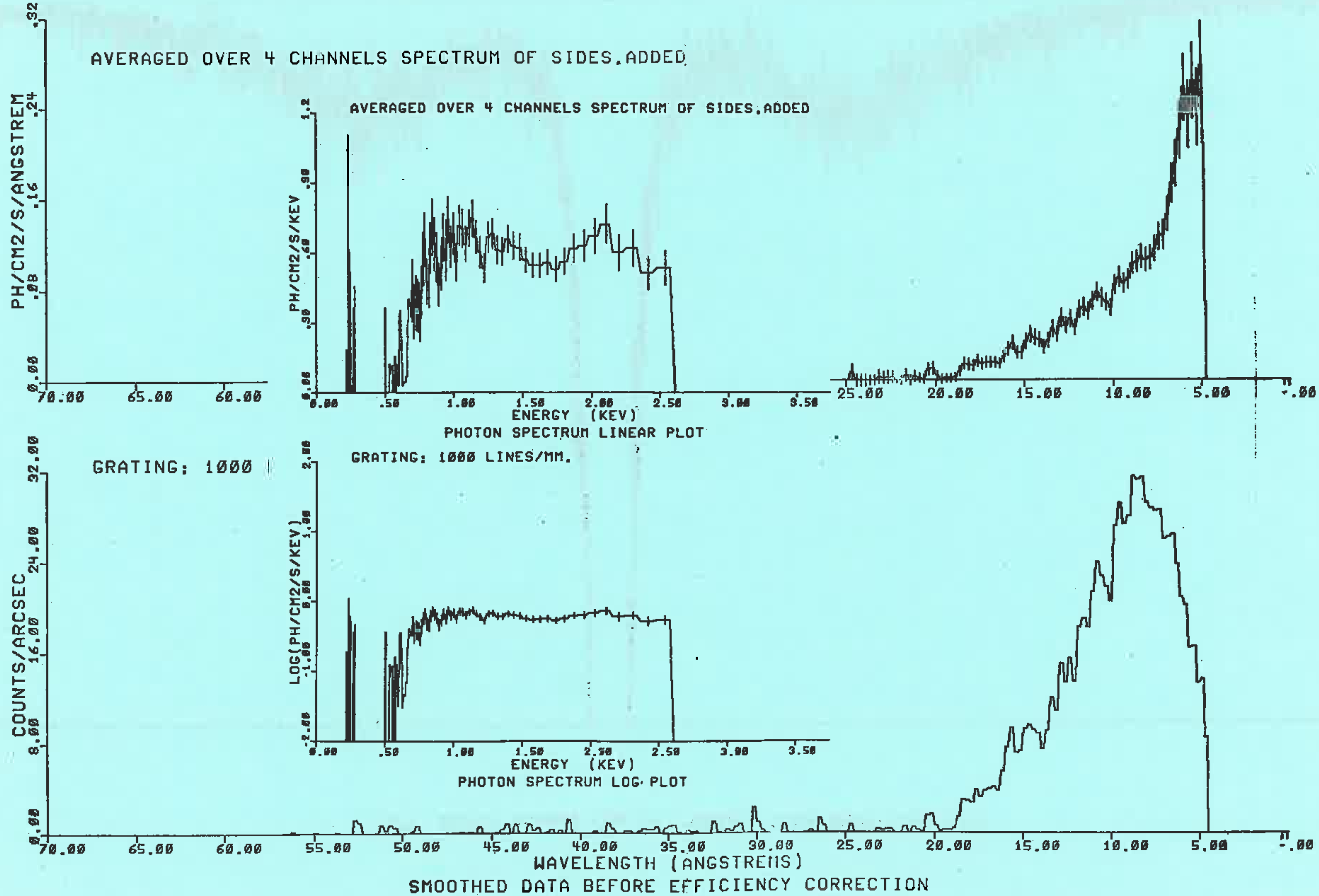
```
9A(M600)  HSEA
          USEA HEAOB:OGS:SMK
          USEA HEAOB:OGS:SMK:WHIZ.SUBDIR

          CONTINUUM.FITS.PRIME
          spectral type                  2
          fitting boundaries             338     1710
          zero order bins                970     1078
          no excluded regions            0
          bin size                       4
          after  λ .100                  c. return
          u. lim                         c. return
          change l. lim                    2
                                         -3
          change deltas                    1  2  3
                                         -1.
                                         -1.
                                         -1.
          change starts                    1  2  3  4  5
                                         1.5           This set for one fit
                                         -.5                  no iterations
                                         21.4
                                         -.4
                                         1.2
          set convergence limit          1
          okay to proceed                c. return
          reanalyze?A. print?P.          P
          reanalyze?A. print?P.          c. return

          PLOT.SPECTRUM

          which option                     1
          bin (wavelength) range, plot 1   230 944      (5 - 50Å left side)
          bin (wavelength) range, plot 2   1275 1510   (5 - 50Å right side)
          to end plots                     0    0
                                           0
```

```
9B(M600)  USEA HEAOB:OGS
        TOGS 4/B 13600./S                parameters can be input with switch
                                             or in parameter file POOGS.PF

10B(M600)  OGSFIT/I=GROUF.PL/P=PEAK/O=FIT.820
             This program does not work March 1984
```



7.3/1 QLPLT output Cyg X-1 (H820) from M600 computer

7.3/2 TOGS output Cyg X-1 (H820) from M600 computer



7.3/3 OGSSAO/SPCTSAO output HZ43 (H945) from VAX computer