ROSAT/WFC Observer Notes 93/1 Rev.1

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Contents

1 The ROSAT Wide Field Camera

The *W*ide *F*ield *C*amera (WFC) on board the ROSAT spacecraft is built and operated by a consortium of UK institutions comprising the *Rutherford Appleton Lab*, *Leicester University*, *Birmingham University*, the *Mullard Space Science Lab*, and *Imperial College London.* Its purpose is the extention of the spectral range covered by the main X-ray telescope of ROSAT down to lower energies. Its four main filters are designed to permit broad band filter spectroscopy in the spectral range from 20 to 200 eV (60 to 600 Å).

The main characteristics of the WFC are:

WFC Mirror parameters:

Mirror type:	Wolter-Schwarzschild I
Mirror material:	Al
Reflective coating:	Au
Number of shells:	3
Field of view:	5° diameter
Geometric area:	456 cm^2
Aperture diameter:	576 mm
Focal length:	525 mm
High energy cutoff (10 % of peak)	210 eV
Half energy width of point spread function:	1.7' at 40 eV (on axis)

WFC Detector characteristics:

Type:	micro channel plate detector
Active diameter:	45 mm
Radius of curvature	165 mm
Channel diameter	12.5 μm

Main WFC filters:

Filter name/type	Mean energy [eV]	Peak effective area WFC+filter [cm^2]	Bandpass [eV] 10 % of peak
S1a: C/Lexan/B	124	~ 1.8 (12.6)	90 - 185
S1b: C/Lexan	124	~ 1.8 (12.9)	90 - 210
S2a/b: Be/Lexan	90	~ 9.5 (22.3)	62 - 111
P1: Al/Lexan	69	~ 0.8 (4.22)	56 - 83
P2: Sn/Al	20	~ 0.2 (1.15)	17 - 24

The survey filters (S1a/b and S2a/b) cover the full 5° field of view, whereas the diameter of the useful field of view of the pointing filters (P1 and P2) is only of the order of 2°. For further details concerning the WFC, the reader is directed to references [4] through [10].

The effective areas listed above are strictly applicable for November 1992. Pre-January 1991 effective areas are given in parentheses. Details about the degradation of the WFC sensitivity after January 1991 may be found in reference [10] and in the appendix.

2 The German ROSAT/XUV Data Centre

The duties of the German XUV Data Centre (GXUVDC) consist

- in the reformating and restructuring of the WFC data as provided by the WFC UK Data Centre at the Rutherford Appleton Lab so as to conform to the MIDAS/EXSAS data formats,
- in performing a standard analysis of the WFC data which will be distributed on paper together with the observer tape, and
- in maintaining an archive of all WFC data.

The activities of the GXUVDC have so far been split up among:

- Astronomisches Institut Tübingen (AIT),
- Lehr- und Forschungsbereich für Theoretische Astrophysik Tübingen (TAT), and
- and Universitätssternwarte München (USM).

The last two institutions have now ended their involvement in the XUV Data Centre and beginning of January 1993 processing and arching of the ROSAT/XUV data is solely performed at the Astronomisches Institut Tübingen.

The activities of the GXUVDC are undertaken in close collaboration with

- Max Planck Institut für Extraterrestrische Physik (MPE),
- Leicester University (UK Science Centre), and
- the Rutherford Appleton Lab (UK Data Centre).

Since feedback is always useful, we greatly encourage all kinds of questions, suggestions, or comments, particularly concerning the WFC Standard Analysis, data tapes, and any experience or problems concering the analysis of WFC data with EXSAS to be reported to the addresses given below.

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3 Data processing summary

Since the beginning of the operational phase about 18 months ago, more than 1300 observations have been processed and mailed to the respective PIs. On average, about one source is detected in every 10 observations. This relatively modest rate is due to the reduction in the WFC effective area after January 1991 (see also reference [4] and the appendix). Below, we list a break up by source category of sources detected in pointed WFC observations with known optical counterparts. As a comparison, WFC sources detected in the WFC All Sky Survey are listed in the second column. A cross correlation with the ROSAT/PSPC All Sky Survey has yielded that most of the WCF sources detected at the XUV Data Centre are also present in the X-ray survey.

Break up by source category:

	Pointed WFC data processed by XUV Data Centre		WFC All Sky Survey Pounds et al. 1992 [11]
WD		26 (39 %)	120 (36 %)
CV		5 (7 %)	17 (5 %)
Cool stars:			
F	4 (6 %)		
G	5 (7 %)		
K	12 (18 %)	29 (42 %)	180 (54 %)
M	1 (1 %)		
RS CVn	7 (10 %)		
B stars		3 (4 %)	9 (3 %)
AGN		4 (6 %)	7 (2 %)

4 The ROSAT/WFC Standard Analysis printout

This paragraph gives a general description of the Standard Analysis printout. Details about the instrumental configuration and the computational methods applied are given in the following paragraph.

The ROSAT/WFC Standard Analysis printout is meant to provide the observer with a first overview of the observation, giving positions and count rates for all detected point sources. Furthermore a test for flux variability is performed. We strongly discourage the observer, however, to base the scientific interpretation of the data on the Standard Analysis printout alone. It is meant instead as a first overview and starting point for a more detailed analysis using the EXSAS data analysis package and the data supplied to the observer in FITS format. The EXSAS package which runs under MIDAS is available both for VMS and Unix systems and a copy of the software can be obtained from MPE.

General notes:
• all coordinates are for equinox 2000.
• all positional uncertainties are $\pm 1\sigma$ (joint confidence region of 68 %)
• the significances of detections and upper limits are generally given in the form $-\ln(p)$, where p is the probability for randomness of the observed signal. These numbers roughly correspond to the following significances on the σ-scale:

$-\ln(p)$:	6.6	10.4	15.1	53.2
σ:	3.0	4.0	5.0	10.0

The Standard Analysis layout as described below refers to the general case of a single pointing. Raster scans (up to 16 individual pointings) will be treated in one Standard Analysis, resulting in a slightly modified layout. The source detection procedure of the merged data from raster scan observations will be performed on a case by case basis and we will get into contact with the PIs individually.

4.1 Overview

The Standard Analysis printout consists of several sections:

Page 2-1 gives an observation log listing integration times, filters used, and the WFC configuration (see section 4.2).

Pages 3-nn show grey scale plots of the full field of view for each individual filter observation. The plots have 160×160 pixels of size 135×135 seconds of arc. The plot frame thus covers a $6^\circ \times 6^\circ$ field. The plots are given in the usual astronomical orientation (north up, right ascention increasing from right to left). The centre of the field of view is given by the target coordinates on the title page.

The term 'filter observation' generally refers to periods of time where no filter change has occured. Exceptionally long 'filter observations' may however be subdivided into several 'filter observations', each containing up to 500 000 events in the low backgound event table (see below).

It should be noted that, in the case of observations using one of the pointing filters or observations in zoom mode, the diameter of the field of view will only be of the order of 2 degrees as compared to 5 degrees for other observations. If the windowing mode is set, the field of view may be as small as half a degree square. For easy comparison between different observations, the plot scale will however be kept constant for all observations.

A screening for high background count rates is performed and only the low background times are used in the images and for the automatic source search (see section 4.3 for details on the screening procedure). No additional corrections or window functions are applied to the measured counts before plotting.

Pages 4-nn give a summary of all detected sources, including the source coordinates as determined from the XUV data as well as background- and flux corrected source count rates for each filter observation (see section 4.4 for more details). For each detected source suggested identifications are given, based on positional coincidence with source positions from the *SIMBAD* catalogue (see also section 4.5). The methods applied to derive positions, fluxes and identifications are described below.

Source coordinates are given in sky pixel coordinates of size 6 seconds of arc (see section 10 for a definition of the pixel coordinate systems used in the Standard Analysis printout), as well as in three different astronomical coordinate systems (equatorial, ecliptic and galactic). The source coordinates are a weighted mean of the source positions found in the individual filter observations. The sky pixel coordinate system is also used to denote the positions of the events in the photon event tables (X_PIX, Y_PIX).

The source count rate is determined using a maximum likelihood technique which adjusts an analytical representation of the WFC point response profile (see section 4.4 for details) to the distribution of the source counts. Only sources above a detection threshold of $-\ln(p) > 10$ are listed in the Standard Analysis printout.

No attempt has been made to derive count rates or accurate source positions for extended sources. The maximum likelihood technique used will however provide reasonable values for source count rates and positions if the size of extended sources is of the order of one or several FWHM of the point response function.

Independent of whether the target was detected, the Standard Analysis always gives an upper limit at the target position. The significance threshold is set to $-\ln(p) = 10$. Depending on the background level, the diameter of the circular detection cell is adjusted in order to maximize the detection sensitivity. The quoted upper limit includes a correction factor allowing for the incomplete coverage of the point response distribution in the detection cell.

Page 5-1 shows a map containing a selection of up to 85 sources from the *SIMBAD* catalogue (see section VI) which fall into the $6° \times 6°$ plot frame of the grey scale plots on pages 4-nn. The plot scale is the same as for the grey scale plots. The sources displayed are selected based on their brightness and source type where source classes thought to be possible XUV emitters are given preference.

Page 5-2 lists all catalogue entries displayed on the map on page 5-1. Suggested identifications with detected WFC sources are marked by "•" and bold printing. While only a selection of up to 85 sources are plotted on page *5-1* the source identification is done within the whole *SIMBAD* catalogue.

Page 6-1 and *page 6-2* list the results for each source detected in any of the filter observations in detail. The first page gives a close up grey scale plot, centred around the best guess source position and using a pixel size of 12 seconds of arc. The size of the plot frame is 32 minutes of arc square. On the second page best guess positions, count rates and additional information is given. This information is partly redundent with the information on pages 4-nn.

4.2 The WFC configuration

The observation log as listed on page 2-1 of the Standard Analysis printout carries the following information on the WFC configuration for each time slot of the observation. This information also appears in the EXSAS descriptor WFC_SLOTS.

1. *Zoom mode:* "**z**" for 'zoom mode on' and " " for 'zoom mode off'.
2. *Telemetry mode:* "**h**" for 'high telemetry mode' and " " for 'low telemetry mode'. The maximum telemetry rates for the high and low telemetry mode are 408 and 200 counts/sec respectively.
3. *Windowing mode:* "**w**" for 'window mode set', "**i**" for 'inverse window mode set' and " " for 'no window set'. When a window is set, the size and position of the window is

specified by four numbers in the range from 1 to 16 which refer to the lower left and upper right corner of a rectangular window set in the space of the nonlinearised detector coordinates. This information is presently not accessed by the EXSAS package.

4. *High voltage:* Relative measure for the WFC micro channel plate voltage. Typical values are close to 160.

4.3 Screening of bad WFC data

Prior to running the automatic source search in the WFC Standard Analysis high background times are screened out. For each filter observation a LEVS threshold is calculated, such that the detection sensitivity for weak, on axis point sources is maximized (LEVS: limited event rate; see section 5.2 for a description of other available event rates). The LEVS threshold chosen for each filter observation is given in the Standard Analysis printout on page 2-1. The data screening is also required to remove extended high background features in the WFC images which would otherwise lead to the detection of spurious point sources.

Events from low and high backgound times as determined by the LEVS threshold are stored in separate photon event tables (see section 5.1 for a description of the relevant file names). Should the observer wish to use all events in a particular analysis, the two tables may be combined using the EXSAS procedure MERGE/PET.

As the data screening may only partially be effective in removing contaminated data, the observer should — in the case of contaminated data — carefully assess the validity of individual detections listed in the WFC Standard Analysis.

4.4 Determination of source position and count rates

The source positions and source counts listed in the WFC Standard Analysis are determined by the EXSAS SOURCE DETECTION package. Additional information can therefore be obtained in the EXSAS manual. The mathematical details of the maximum likelihood method used are described in reference [1], a copy of which can be obtained from AIT.

Point response function

Ground based PANTER calibrations as well as in-orbit measurements have revealed that the point response of the WFC is not well described by a Gaussian profile. Satisfactory fits have however been obtained by fitting a two dimensional King or Moffat profile plus exponential correction term to the point response. The positions and count rates given in the WFC Standard Analysis are determined using such a profile. The exact functional form of the point response used in the WFC Standard Analysis is:

$$F(x-x_0, y-y_0) = \frac{1}{1+Q}[\frac{IN-1}{\pi f_\alpha a_\alpha^2}\frac{1}{(1+(r/r_\alpha)^2)^{IN}} + Q\frac{\exp(-r/r_\beta)}{2\pi f_\beta a_\beta^2}]$$

Where: $r/r_\alpha = \frac{\sqrt{(x-x_0)^2+(y-y_0)^2/f_\alpha^2}}{a_\alpha}$, similarly for r/r_β.

x, y = coordinate system aligned along the PSF major and minor axes. The minor axis always points to the optical axis.
f_α = ellipse axial ratio (minor/major) for Moffat contribution.
f_β = ellipse axial ratio (minor/major) for exponential contribution.
a_α = scale length for Moffat contribution.
a_β = scale length for exponential contribution.
IN = power index of Moffat contribution.
Q = relative normalization (fraction of counts in exponential contribution).

The six parameters $f_\alpha, a_\alpha, IN, f_\beta, a_\beta$ and Q have been determined as a function of off axis angle and energy using PANTER measurements and in orbit data:

off axis angle [′]	α_α [*skypix.*]	f_α	IN	α_β [*skypix.*]	f_β	Q
Energy:	10.0 eV					
0.0	3.64	1.00	1.43	24.0	1.0	25.5
37.8	5.91	0.98	1.37	24.0	1.0	0.0
69.0	7.15	0.93	1.42	24.0	1.0	0.0
98.4	12.62	0.83	1.55	24.0	1.0	0.0
129.6	17.36	0.67	1.47	24.0	1.0	0.0
Energy:	$\geq$ 52.3 eV					
0.0	4.85	1.00	1.35	24.72	1.0	26.5
37.8	6.67	0.92	1.34	24.72	1.0	0.0
69.0	8.77	0.88	1.41	24.72	1.0	0.0
98.4	13.27	0.77	1.43	24.72	1.0	0.0
129.6	20.25	0.75	1.54	24.72	1.0	0.0

Using the EXSAS SOURCE DETECTION package with WFC data

When using the EXSAS SOURCE DETECTION package with WFC data, care should be taken that the instrument specific values in the parameter files have their correct settings. These are:

SKYPIX_PER_IMAPIX	7.0
SKYPIX_SIZE	6.0
DETPIX_SIZE	9.0
DETECTOR_CENTER	0 0
SKYPIX_CENTER	0.0 0.0
PSF_TYPE[1]	E2KING2
NUM_RUNS	2
DEAD_X_ROWS	170 3 0 0 0 0
DEAD_Y_ROWS	170 3 0 0 0 0
CUT_RADIUS_FWHM	10.0
CUT_RADIUS	15.0
FWHM_CAL_FILE	OP*f*BLR.TBL

[1] not applicable in present EXSAS release

Please make sure that the parameter file SOPAR.PAR is present and that the parameter FWHM_CAL_FILE is set to its correct value (OPfBLR.TBL) when running the EXSAS SOURCE DETECTION package on WFC data. If no SOPAR.PAR file is present, default values applicable to the ROSAT PSPC take effect and the results will be incorrect !

With the present release of EXSAS, WFC source detection can be performed up to the task EXDM (map detect). Observers interested in running the maximum likelihood source search should contact the XUV Data Centre.

For a complete description of the EXSAS SOURCE DETECTION package, the reader is refered to the EXSAS manual.

We will now go through some of the values listed in the WFC Standard Analysis for each detected source in detail:

Pixel coord. [sky pix.]: Sky pixels are defined in such a way that the centre of pixel (0,0) refers to the target coordinates which also coincide with the centre of the full images given in the Standard Analysis printout. The pixel size is 6" $\times$ 6". The errors given are formal statistical 1 σ errors determined by the method described in [1] and [2]. The investigation of WFC sources with known optical counterparts has revealed that the actual errors are much larger than these formal statistical errors. For an on-axis source (off-axis angle $< 1°$), the estimated positional uncertainties (90 % confidence radii) are 30" for strong and 45" for weak sources.

Source extent: As mentioned above, the WFC Standard Analysis does not attempt to derive accurate positions and fluxes for extended sources. Deviations of the source profile from the expected point source profile are however measured by the source extent parameter which is definded as follows:

The source extent is estimated by substituting the scale length of the Moffat contribution $a_\alpha = a_{\alpha\, psf}$ to the point response with $a_{\alpha\, tot}$ defined by:

$$a^2_{\alpha\, tot} = a^2_{\alpha\, psf} + a^2_{\alpha\, ext}$$

where $a_{\alpha\, ext}$ describes the deviation of the source distribution from the point response. The quantity $a_{\alpha\, ext}$ is listed on pages 6-nn of the Standard Analysis printout under *source extent*

Likelihood of extent: The likelihood of extent is given by the expression $L_p - L_e$, where L_p is the best fit likelihood of a point source fit and L_e is the maximum likelihood which is obtained by also varying an additional extent parameter. See reference [1] for details.

Corrected count rate: The corrected count rate C_{corr} is determined by $C_{corr} = S/T$ where:

S: Maximum likelihood source counts, normalized to optical axis
T: Accepted integration time at position of source

Background counts: Background counts are given per image pixel (42 arc seconds square) per filter observation.

Likelihood of existence: The likelihood of existence is given by the expression $L_S - L_{S=0}$ where L_S is the best fit likelihood and $L_{S=0}$ is the likelihood obtained by setting the source flux to 0. See reference [1] for details.

Blur radius: Full width half maximum of point response.

On axis efficiency normalization: The maximum likelihood source counts described above incorporate a correction which normalizes the count rates to the on-axis case. The main contribution is the correction for the telescope vignetting, but efficiency variations over the face of the detector are also included.

Total integration time: Nominal time when the instrument is turned on and the sky location of interest is in the field of view.

Accepted integration time: Effective integration time, when the detector count rate is below the LEVS threshold. The determination of the LEVS threshold is described in section 4.3. The term 'effective integration time' here refers to the total integration time minus the telemetry dead time, multiplied by the on axis efficiency normalization factor.

Variability information: Two different variability tests are performed in the WFC Standard Analysis:
1. A χ^2 test of the flux corrected and background subtracted source count rate. The bin width is adjusted in such a way, that at least 20 source counts are accumulated in each bin. The shortest time scale on which variability can be detected is therefore a function of the source strength.
2. A Kolmogorov-Smirnov test of source and background events separately.
For both methods, the source events are accumulated from a circle of radius $3\sigma_{PSF}$, centred around the best guess source position. Background events are accumulated from a concentric annulus with inner radius 10 σ_{PSF} and outer radius 15 σ_{PSF}. Probabilities for variability are given in the form $-\ln(p)$, where p is the probability for randomness of the observed variability.

4.5 Identification of detected sources

For each source detected in the WFC Standard Analysis all entries of the SIMBAD catalogue within one minute of arc of the best guess WFC position are given.

The Simbad catalogue entries listed are as follows:

1. Name of the object. If there are many names, the following preference is used: HR, GJ, HD, SAO, BD ... and MRK, NGC, PKS, QSO, 3C, 4C, 5C, ESO ...
2. Type of object. 0: star, 3: galaxy, 1: other (cluster,...) or not defined (radiosource, X-ray source, ...)
3. Visual magnitude
4. Blue magnitude
5. "V" for variable star
6. Spectral type for stars (type=0) or morphological type for galaxies (type=3).
7. "P" for parallax available; "U" for UV excess object; "X" for X-ray source

5 Description of the files on the observer tape

The FITS files on the observer tape constitute a complete set of data and calibration files necessary to perform a detailed analysis of the data using the EXSAS package and MIDAS. It is therefore required that MIDAS/EXSAS are installed on the observer's computer system. All files come with the standard EXSAS descriptor header and where applicable the EXSAS special descriptors are also present. The reader is refered to the EXSAS documentation for details. Some additional descriptors are only for internal use in the Standard Analysis.

If MIDAS and/or EXSAS are not available at the computer site of the observer, ESO and/or MPE should be contacted to obtain a copy of the software.

• We would like to mention here once more that as a standard procedure data tapes are only supplied to the observer when sources have been detected in the Standard Analysis run at the XUV Data Centre. Data tapes for all other observations are certainly available on request from the Data Centre. Once an WFC observation becomes public (see also section 8) it will in the future be possible to download the full images and maps of each filter observation (in compressed form) directly from a computer disk at the XUV Data Centre.

The files on the observer tape should be dumped onto disk by performing the MIDAS commands:

MIDAS 001> SET/CONTEXT EXSAS
MIDAS 002> INTAPE/ROD 1-99 TAPEn ! (n = 0, 1, 2 ...)

Make sure that TAPEn is set to the name of the tape device used. In this way the original file names will be restored on the observer's disk. The first two letters of all WFC files will be OP (for Observation Period), followed by a letter A, B, C ... numbering the individual filter observations. Calibration file names are followed by an additional three letters describing the type of the file. The file extention of all files will, according to the general MIDAS convention, be either '.TBL' for MIDAS tables or '.BDF' for MIDAS bulk data frames. In the template file names listed below, f stands for A, B, C, ... The names of the corresponding PSPC files are given in section 5.3.

5.1 Data files

Photon event files [OPf.TBL]: Depending on the number of filter observations of a particular observation there will be one to several photon event tables (file type PEM), containing all events from the low background times as determined by the LEVS threshold (see section 4.3). In exceptionally long observations (i.e. more than 500 000 events per filter observation) it has been necessary to split the individual filter observations into chunks which can be digested by MIDAS.

Full images [OPf.BDF]: For each filter observation a full image of size 512×512 pixels covering a $6° \times 6°$ field and centred around the target coordinates is supplied on the observer tape. The image contains the same events as the corresponding photon event table OPf.TBL.

Rejected event files [OPfDIFn.TBL]: Depending on the number of events (eg. more than 500 000) one to several separate tables (numbered by index n) are created for each filter observation. For details on the screening of the data see section 4.3.

EXSAS SOLST files [OPfMLS.TBL]: This is the main output file of the EXSAS SOURCE DETECTION package, which gives the positions and source counts of all sources detected in one filter observation as determined by a maximum likelihood fit using the point response profile described in section 4.4.

5.2 Calibration files

Vignetting maps [OPfINS.BDF]: The vignetting map gives for each pixel the on-axis-normalization factor, which is set to 1.0 on the optical axis and drops to values of order 0.5 for large off axis angles. The correction for telescope vignetting is the main contribution but differences in efficiency over the face of the detetctor are also included. Please note that the maximum of the effective area of the WFC does *not* occure on the optical axis. This results in values greater than 1.0 at some positions of the vignetting maps.

Exposure maps [OPfMEX.BDF]: Exposure maps give the effective integration time in seconds for each pixel. Differences in exposure for different parts of the image may occure when the orientation of the spacecraft changes during an observation. The exposure map corresponds to the photon event table, containing only the good events.

Vignetting and exposure maps are calculated for the low background times as determined by the LEVS threshold only.

Detection masks [OPfDEX.BDF]: For each image a detection mask is supplied, marking the region of the image where a source search was performed in the WFC Standard Analysis. The detection mask is required as input by the EXSAS SOURCE DETECTION package.

Attitude tables [OPfATT.TBL]: The attitude table lists the position of the optical axis of the WFC, as well as the roll angle, in time steps of 1 second. See reference [3] for details. The attitude table is required as input by the EXSAS CORRECTION package.

Position tables [OPfPOS.TBL]: The position table lists the orientation and orbital position of the spacecraft in time steps of 60 seconds.

VVANG	Angle between velocity vector and telescope axis [deg]
X/Y/ZSATELLITE	Cartesian equatorial coordinates of spacecraft with respect to earth baricentre [m]
RA, DEC	Viewing direction [deg]
ROLL	Roll angle [deg]

Rates tables [OPfRAT.TBL]: The rates table lists the following rates [sec^{-1}] in time steps of eight seconds:

TEVS	Total events output by the detector preamplifiers
VEVS	Valid events, i.e. TEVS within the pulse height limits
LEVS	Limited events, i.e. VEVS within the electronic f.o.v.
AEVS	Accepted events, i.e. LEVS entered into telemetry queue
FEVS	Final events, i.e AEVS telemetered to ground

The rates table is required as input by the EXSAS CORRECTION package.

Effective area tables [OPfEFF.TBL]: The effective area tables give the effective area of the instrument as a function of energy and off axis angle. Due to the degradation of the WFC effective sensitivity they are strictly only valid for the date of the corresponding observation. The units used are $[cm^2]$ for the effective areas, $[keV]$ for the energies and minutes of arc for the off axis angles. In the case of the WFC one effective area table per filter observation is supplied. The effective area tables are required as input by the EXSAS CORRRECTION package.

Effective area images [OPfEFF.BDF]: The effective area image is a three dimensional data structure giving the effective areas of the instrument as a function of energy and position on the WFC detector. The effective area image is required as input by the EXSAS CORRECTION package.

Detector response matrices [OPfDRP.BDF]: The detector response matrix is mainly relevant for instruments, such as the ROSAT/PSPC, which have an intrinsic energy resolution. In the case of the WFC the detector response matrix, which is required as input by the EXSAS SPECTRAL PACKAGE, is only supplied for compatibility purposes.

Point response tables: The shape of the WFC point response function is supplied in two differnt forms:
1) In the *blur radius tables* [OPfBLR.TBL], the FWHM of the point response function is given as a function of energy and off axis angle. The blur radius table is required as input by the EXSAS SOURCE DETECTION package.
2) In the *cumulative profile tables* [OPfPSF.TBL] the radii at which the integrated point response profile has reached 10, 20, 30 ... 90 % of the total are given for several off axis angles.

5.3 Summary of file names

WFC name	corresponding PSPC name
OPf.TBL	EVENTS.TBL
OPf.BDF	IMAGE.BDF
OPfDIFn.TBL	DIFEVENTS.TBL[1]
OPfMLS.TBL	SOURCE.TBL
OPfINS.BDF	INSTRMAP.BDF[2]
OPFMEX.BDF	EXPOSURE.BDF[3]
OPfDEX.BDF	EXSAS_CAL:MASK.BDF
OPfATT.TBL	ATTITUDE.TBL
OPfPOS.TBL	ORBIT.TBL
OPfRAT.TBL	EVENTRATES.TBL
OPfEFF.TBL	EXSAS_CAL:EFFAREA_PSPCB.TBL
OPfEFF.BDF	–
OPfDRP.BDF	EXSAS_CAL:DRMPSPC.BDF
OPfBLR.TBL	EXSAS_CAL:FWROPS.TBL[4]
OPfPSF.TBL	EXSAS_CAL:PSF.TBL

[1] No strict correspondence: WFC table contains high background times.
[2] PSPC instrument map is given in detector coordinates; WFC instrument map is given in sky coordiates (same binning as image).
[3] No strict correspondence: WFC frame contains raw integration times. If effective integration

times are required, frame may be multiplied with instrument map using the MIDAS command COMPUTE/IMA.
[4] PSPC table is empty (only descriptors are required by EXSAS).

6 Spectral fitting of WFC data

As the WFC has no intrinsic spectral resolution, no information on the source spectrum can be obtained from a single filter observation alone. At least two filters or additional XRT data are needed. A typical application will be the spectral fitting of PSPC data with one additional spectral point provided by an S2 filter observation of the WFC. With the EXSAS SPECTRAL PACKAGE it is now possible to perform simultaneous spectral fits of ROSAT data from several instruments (please check the EXSAS manual for details). When using WFC data in a spectral fit with EXSAS the WFC data have to be treated in essentially the same way as the PSPC data. Here we want to address some points where the data preparation procedure deviates from PSPC data preparation: WFC data are treated in such a way that each filter observation counts as a separate instrument with its own detector response matrix and effective area table. These are provided on the observer tape. As the WFC has no intrinsic energy resolution, the WFC photon event tables do not have :AMPL and :RAW_AMPL columns. In order to maintain consistency with the PSPC the WFC source and backgound counts nevertheless have to be extracted using the EXSAS PROJECTION command BIN AMPLITUDE. EXSAS will then produce a raw spectrum table containing only one energy bin. Please note that it is not possible to run RROJECTION in correction mode in conjunction with WFC data. Instead, the CORRECT/SPECTRUM command has to be used. The correction may be performed either in photon mode or in attitude mode in which case the attitude table (OPfATT.TBL) supplied on the observer tape has to be used. Contrary to the correction of PSPC data a 3-d efffective area image (OPfEFF.BDF) is used, instead of the usual effective area table for performing the off axis correction. The EXSAS command MERGE/SPECTRA may than be used to combine the raw spectra, correction vectores and response matrices from the different instrumes. Please check the relevent sections of the EXSAS manual.

7 Main differences between reprocessed data and first processing

Effective areas: WFC effective areas are now based on the new WFC Master Calibration File MCF-11 which was issued by the Rutherford Appleton Lab in November 1992. These effective areas now include the time dependent degradation of the WFC after January 1991. The effective areas listed in the OPfEFF.TBL and OPfEFF.BDF supplied on the observer tapes are therefore interpolated for the epoch of each observation (make sure to use the appropriate effective area file). Future changes in the WFC calibration (see below) will be made available to the PIs through a public computer account in Tübingen. Time dependent correction factors to be applied to the pre-January 1991 effective areas are listed below. Please also note the memo printed in the appendix.

Date	MJD	WFC Filter:		
		S1[1]	S2	P1/P2
Jun 1, 90	48034	1.0000	1.0000	1.0000
Jul 8, 90	48080	1.0000	1.0000	1.0000
Jan 26, 91	48282	0.6850	0.8300	0.6850
Mar 3, 91	48318	0.1200	0.2970	0.1200
Mar 13, 91	48328	0.1128	0.1540	0.1128
May 8, 91	48384	0.0738	0.1100	0.0738
May 9, 91	48385	0.1820	0.3100	0.1820
Jun 19, 91	48426	0.1360	0.1980	0.1360
Oct 18, 91	48547	0.1470	0.2600	0.1470
Mar 21, 92	48702	0.1810	0.3260	0.1810
Sep 18, 92	48883	0.1800	0.4260	0.1800
Nov 14, 92	48940	0.1800	0.4260	0.1800

[1] an additional factor of 0.779 has to be applied to the the S1 effective areas (see also the memo printed in the appendix).

Observations processed later than Oct 7, 92 at the XUV Data Centre (see processing date in the MIDAS descriptors) do already include the time dependent degradation of the WFC effective areas (see Table below).

processing date	calibration in use
before Oct 7, 92	pre-Jan 91 effective areas
Oct 7 to Oct 30, 92	MCF-10
after Oct 30, 92	MCF-11; see also memo printed in the appendix

High backgound times: For each filter observation the photon event table is now divided into a low background (OPf.TBL) and one to several high background (OPfDIFn.TBL) tables. The low background table contains the events on which the automatic source search in the WFC Standard Analysis is run (also see section 4.3 and 5.1).

LEVS threshold: The algorithm calculating the LEVS threshold used for the determination of the low background times has been modified, such that now a larger proportion of the total integration time is used for the automatic source search (see also section 4.3).

Earthblock: It has been found that in a small number of observations the data supplied on the observer tape included time periods when the instrument was pointed towards the earth. This has in some cases also led to erroneous source count rates in the WFC Standard Analysis. The problem has been corrected for observations processed later than October 1992.

Variablity page: Observations processed after October 1992 do not contain ligh curves plots anymore for sources found to be variable.

Descriptors and column labels: A number of MIDAS descriptors and MIDAS table column labels were modified to achieve full consistency with EXSAS.

• The above changes and some additional fine tuning of the source detection algorithm have generally resulted in somewhat higher values for the likelihood of existence printed for each source detected in the WFC Standard Analysis (it may be that your observation is one of the exceptions !). Correspondingly the upper limits given for the detection of on axis point sources which are printed in the WFC Standard Analysis are now slightly lower. In addition the number of spurious sources detected in the WFC Standard Analysis has been reduced.

8 Archive access and data rights

It has been agreed that, as with the ROSAT X-ray data, the exclusive ownership rights of ROSAT/WFC data will expire one year after the data have been made available to the PI.

The XUV Data Centre will make available a list of all public WFC observations. This list will be updated periodically and will be kept as a computer file on the ROSAT service area at the MPE, as well as on a public computer disk in Tübingen (see below). The archive of public WFC data kept at the XUV Data Centre in Tübingen will eventually contain *all* pointed WFC data, including those of British and US pointed observations. The German share of pointed WFC data will in return be made available to British and US observers. Public ROSAT/WFC data sets (Standard Analysis printout and computer tape) will be available from the XUV Data Centre at the address given above. In addition, the WFC archive at the XUV Data Centre in Tübingen will support remote logins and down loading of suitably compressed WFC data sets for a detailed analysis using MIDAS/EXSAS. The on line archive which is expected to open early in 1993 will contain:

- the WFC observation log,
- an up-to-date set of calibration files,
- a results data base containing count rates, positions, and where available identifications of all detected sources,
- full images and exposure maps for all observations and additionally,
- a complete set of data and calibration files for those observations where sources have been detected in the WFC Standard Analysis.

Access to online archive:

SPAN: 29382::XUV_ARCHIVE:[XUV]
FTP: AIT.PHYSIK.UNI-TUEBINGEN.DE
login as "XUV", password "XUV_ARCHIVE"

9 Bibliography

The XUV Data Centre compiles a data base of all sources measured with the WFC during the pointed phase of the ROSAT mission. This data base contains positions, fluxes, identifications and a bibliography of papers reporting on WFC observations. In order to keep this data base as complete as possible, the observers are asked to report identifications of the sources detected in their WFC observations to the Data Centre and also to supply preprints of papers concerned with WFC pointed phase observations to the Data Centre.

10 Units, constants and terminology

Pixel sizes:

Sky pixels: This is the unit of the *X_PIX* and *Y_PIX* event coordinates in the photon event tables. The pixel size is 6" $\times$ 6". The lower left corner of pixel (0, 0) coincides with the target coordinates given on the title page of the Standard Analysis printout. The X coordinate increases from east to west (left to right) and the Y coordinate increases from north to south.

Detector pixels: This is the unit of the *X_DET* and *Y_DET* event coordinates in the photon event tables. The pixel size is 9" $\times$ 9". The coordinate system is fixed on the detector and the lower left corner of pixel (0, 0) coincides with the optical axis of the WFC.

Image pixels: The image pixel size is 42"$\times$42". This pixel size is used for the automatic source search in the WFC Standard Analysis as well as in the full images, which are supplied for each filter observation on the observer tape. The full images have 512 $\times$ 512 pixels, covering a field of $6^\circ \times 6^\circ$.

Plot pixel sizes used in the WFC Standard Analysis printout: The full images displayed on pages 3-nn have a pixel size of 135" $\times$ 135". The full resolution images given for each detected source on pages 6-nn have a pixel size of 12"$\times$12". In both cases 160$\times$160 pixels are displayed.

Time units:

Spacecraft clock: The event times in the photon event tables, as well as the times in the TIM_SEL descriptor and the times in the attitude and rates tables are given in spacecraft clock units. The basic spacecraft clock unit is 1/32 second. For compatibility with the ROSAT/PSPC data, all spacecraft clock times have however been converted to seconds after MJD 48043.879733796, which coincides with the beginning of the ROSAT mission.

UTC: Beginning and end of each filter observation are given in spacecraft clock units (EXSAS standard descriptor OBS_CLOCK) and as UTC times in the form DD-MMM-YY HH:MM:SS.SSS (EXSAS standard descriptors: OBS_DATE and OBS_UT). Times in the WFC Standard Analysis printout are generally UTC times in the above format.

Terminology:

EXSAS: Extended *S*cientific *A*nalysis *S*ystem. This software package was specially developed for ROSAT data analysis and runs under MIDAS. The FITS files on the ROSAT/WFC observer tape have been prepared to conform to the EXSAS data formats.

Filter observation: Section of an observation where no filter change has occured. Exceptionally long observations may be subdivided into several 'filter observations' each containing up to 500 000 events in the low background table. An observation is made up of one to several filter observations.

Slot: Uninterrupted segment of an observation where the WFC configuration (see below) is kept constant.

WFC configuration: This term refers to the status the WFC with respect to zoom-, telemetry- and windowing mode. See section 4.2 for details.

Raw integration time: Sum of the duration of all slots of an observation.

Total integration time: Raw integration time, when the sky location of interest is in the field of view.

Effective integration time: Total integration time minus telemetry dead time, multiplied by on axis efficiency normalization factor. In the effective areas listed in the observation log no on axis efficiency normalization factor is included.

Accepted integration time: Effective integration time, when the detector count rate is below the LEVS threshold. The determination of the LEVS threshold is described in section 4.3.

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Appendix: Status of WFC calibration:

Here we reprint a memo communicated by Julian Osborn, Leicester University which outlines the present status of the WFC calibration (November 1992):

A new WFC Master Calibration File (MCF-11) has recently been created. It is distinct from the previous calibration file (MCF-10) in three ways:

1) The S1a and S1b effective areas are reduced by an energy-independant factor to 0.779 of their previous values.

2) The interval over which the actual decline in effective area is available has been extended to Nov 1992.

3) The time history of the decline in the effective area in the P1 and P2 filter bands more accurately matches the available data.

This new calibration is based on the calibration phase observation of HZ 43 in the S1a and S2a filters, and has been confirmed with 8 other sources. The absolute calibration error in the S1 and S2 filter bands is believed to be of order 10 %, whereas the error for the P1 and P2 filter bands is thought to be of order 30 %.

No energy-dependant correction to the original calibration of the S1 filters is now thought to be necessary. In addition, a previously reported factor 10 error in the P2 effective area has in fact never existed. This large reported factor was caused by a software error.

This MCF is almost certainly not the final word on the WFC calibration. The new PSPC matrix recently created has a significantly different low energy response. Because the WFC has had some cross-calibration confirmation from PSPC spectral fits, it is inevitable that the new matrix will help with the WFC calibration. In addition, the physical reason for a 0.779 factor applied to the S1 filter areas is not established. It may be that continuing work on the emission spectrum of HZ 43 will allow a consistent solution in the future.